



western union

# Technical Review

MAGAZINE  
SPRING 1968

$y = ax^n$

$$f = \frac{1}{T}$$

... dBm

cpm

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SPRING 1968

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COVER: A binary signal with white noise and impulse noise superimposed on the intelligence.



Mr. T. F. McMains, Vice President of Business Relations, has been responsible for Western Union's Response to the F.C.C. Inquiry.

FCC

# BEGINS TO EXAMINE The COMPUTER/ COMMUNICATIONS INTERDEPENDENCE

by T. F. McMains

Vice President—Business Relations

Western Union recently participated in a Federal Communications Commission Inquiry which may have landmark significance. Other participants included a broad spectrum of representatives from the commercial, government, and academic sectors. The Inquiry is designed to illuminate and explore regulatory and policy problems presented by the interdependence of computer and communication services and facilities. Those affected by the outcome of this and subsequent related inquiries may be the domestic and international common carriers, computer equipment manufacturers, offerors of time-shared computing services, and the general user of common carrier data communica-

tions services.

The regulatory and policy problems which concern the FCC spring from two key facts:

- (a) Modern stored program general purpose digital computers can be used as communications control devices—in message switching and circuit switching applications. Additionally, the traditional functions of data processing can be performed at the same time, on the same machine.
- (b) Modern general purpose digital computers can be connected on-line to common carrier data communications facilities. Thus, with

the support of the common carrier communication facility, an entrepreneur can offer, "for hire," remote time-shared data processing and information retrieval services.

This convergence of communications with computers leads to some interesting consequences. Since the same computer can be used as both a communications switch and a data processor, a non-regulated entity offering communications linked processing services is in a position to perform, concurrently, communications switching services for his subscribers—a traditional common carrier function. Conversely, the common carrier who avails himself of modern computer technology to provide computerized switching, is in a position to concurrently sell data processing services.

#### The Big Issue—to Compete or Not

The mechanism therefore exists for the communications carrier and non-regulated entities to compete in a regulated field—communications, and in a non-regulated field—data processing.

Thus, the first potential problem area manifests itself. Should this competition be permitted or not? Are these new activities adequately covered by existing legislation and legal precedent? Is there now a blurring of the distinction between regulated and non-regulated activities as defined by Title II of the Communications Act of 1934? These are the regulatory problems of concern to the FCC.

A second problem area concerns policy matters—of the FCC and of the common carriers. The issues here relate to policies on matters such as accounting procedures, rate making, tariffs, and service offerings. Do these policies, as currently practiced, have the potential for inhibiting effective competition and growth in the field of the communications-related data processing industry?

A third area of interest emerging from the relationship between computers and communications is the possible misuse of computerized data bases linked to communications channels. These may contain large amounts of personal and commercial information such as credit status and corporate accounts. Does this centralization of information lead to a potential invasion of personal and corporate privacy which would be inconsistent with the goals of a free society? Can this privacy be safeguarded adequately?

#### Is Change Needed?

In recognition of these three major issues: adequacy of existing regulation, carrier and Commission policies, and privacy, the FCC Computer Inquiry was initiated. The Notice of Inquiry, issued in November 1966, contained 10 specific questions bearing upon the future direction of the communications-related data processing industry. In condensed form, these ten inquiry items are:

**Item A:** Describe the uses, current or contemplated in the next decade, of computers and communication channels and facilities for message or circuit switching, data processing, information retrieval, and combinations of these services.

**Item B:** Describe the basis for and the structure of charges to the customers for the services listed in A above.

**Item C:** Under what circumstances, if any, should any of the services in A be deemed subject to Title II of the Communications Act of 1934, when (a) involving the use of communications facilities, when (b) furnished by a communication common carrier, when (c) furnished by a non-carrier?

**Item D:** Assuming that any of the services in A are subject to the Communications Act, would it be in the public interest that these services evolve in a free competitive market? If so, are changes in existing law required?

**Item E:** Assuming that any of the services in A are not subject to regulation under the Communications Act, is it in the public interest that they be regulated by an appropriate government authority? If so, what should be the nature of such legislation?

**Item F:** Are the existing regulatory procedures of the Commission consistent with insuring fair competition between the common carrier and the non-carrier in the sale of computer services involving communications?

**Item G:** Are the rate structures and practices contained in the existing tariff schedules of the common carrier compatible with the present and anticipated requirements of the computer industry and its customers?

**Item H:** What new common carrier tariff offerings or services will be required to meet the present and anticipated needs of the computer

industry and its customers?

**Item I:** In what respect are the present day transmission facilities of common carriers inadequate to meet the requirements of computer technology—including those for speed and accuracy?

**Item J:** What measures are required by the computer industry and common carriers to protect the privacy of data stored in computers and carried over communication facilities?

If we take an overview of these ten Inquiry Items a pattern emerges: Item A is essentially factual in nature. It seeks information in two areas—(a) technology, or how computers and communications are configured to perform a given service, and (b) the market place, or the present and future market significance of these services. Item B asks for pricing information concerning these services.

Items C through E are concerned with the scope of existing legislation and its impact upon the growth of the communication and data processing industries. These items are also aimed at resolving the extent to which competition is desirable in the communications-linked data processing industry.

Items F and G refer to potential policy problems emanating from the existing procedures of the Commission and the carriers. The thrust of these items is to determine if these present policies inhibit growth and competition within the communications/data processing industry.

Items H and I are designed to determine if the common carrier service offerings and transmission plant are keeping pace with the needs of the data processing industry.

The intent of Item J, the privacy question, is self explanatory. Although it is in a sense unrelated to the nine previous regulatory and business oriented questions, it still addresses itself to a very important philosophical problem which may affect the direction and growth of the communications-related data processing industry.

#### The Law is Adequate

Western Union's approach to the key regulatory questions (Items C, D, E) is that no changes are required in the Communications Act of 1934 to encompass the services listed in Item A. Our position is that data processing and information services do not fall within the scope of the Communications Act and that moreover they should

remain unregulated. On the other hand, communications services (including message and circuit switching) should remain regulated in accordance with already established legal precedents. With respect to a computer data processing offering which also provides a communications service, our position is that—if this service is provided on a "for hire" or "holding out" basis, then the communication portion of the package is subject to regulation.

In developing this position we pointed out that there is no essential difference in function between an electromechanical switch and the computer switch. The general purpose computer used as a switch is the logical evolution from the electromechanical system, in step with the evolution of technology. In fact, the computer merely replaces on a one-for-one basis, electromechanical logic and storage elements with computer program logic and computer peripheral storage. The important fact is that the law requires the regulation of a communication service offered "for hire," whether it is implemented by a computer or any other piece of hardware.

Since the same computer operating in a multi-programming or multi-processing mode can concurrently perform communications switching as well as what we know today as "data processing"; it was necessary to define the difference between these two functions. The resolution of this difference is required because the Communications Act requires regulation by the F.C.C. of the communications service but exempts from regulation non-communications services, even though both may be performed in the same computer or device.

#### Functions are Different, Separable

A communication function may be said to take place if intelligence or information (e.g. a string of alphanumeric characters) is transmitted by wire or radio between two points without any change in the semantic content. If on the other hand a computer changes or transforms semantic content (e.g. conversion of hours worked to a pay check), then a data processing function has taken place. We then stated that it is possible to separately identify these two functions—communications switching and data processing, and that no problem exists in applying existing regulation to a communications service implemented by a computer which is simultaneously being used to render data processing services.

Our answers to the policy oriented inquiry items (F and G) were consistent with our stand that no changes in existing legislation are necessary. We believe that existing procedures for the regulation of activities within the Commission's jurisdiction are generally adequate at present. However, re-examination of some specific policies, such as rate making, may be required in order to achieve fair and effective competition in the sale of "non-regulated" computer services involving communications.

#### **Confident of Carrier Capability**

In responding to Item H (New Common Carrier Offerings) we described our existing plans for the Western Union Integrated Message/Data System and cited some of the computer communications needs which it will support. We also listed some services which would probably be required in the future such as: lower cost service to interactive time sharing users, broader range of transmission speeds, bulk data transfer service, and ultra-high speed burst transmission.

Item I (Adequacy of Transmission Facilities) permitted us to comment on the status of the total common carrier transmission plant and to indicate the direction of technological innovation. Our position here is that the existing predominantly analog transmission plant, (one based on frequency division multiplex and linear repeaters) when used with off the shelf error detection and control techniques, is adequate for the majority of data communication users with respect to the criteria of speed, adequacy, and availability. We recognize that a digital transmission plant (one based on time division multiplex and non-linear regenerative repeaters) will probably be more cost-effective for future needs. We believe that Western Union, whose existing transmission plant is predominantly conditioned for data, is in an excellent position to evolve to pure digital facilities in step with technological developments and as user needs crystallize.

On the issue of privacy (Item J) we described the procedures that can be taken to protect the unauthorized access of computer stored informa-

tion. Existing hardware and software techniques, supplemented by physical surveillance of the user terminal and the computer terminal areas, offer means for adequate protection of information. For example, appropriate computer software, coupled with a system of passwords known only to authorized users, can effectively curtail unauthorized access from remote locations. At the computer area careful screening of operating personnel and physical surveillance will be required. In many respects the protection of computerized information is rendered more manageable than protecting information stored in conventional letter files. The very fact that data are stored in magnetically coded regions on tapes and drums makes unauthorized retrieval all but impossible except by highly trained intruders with an intimate knowledge of the computer operating system.

Concerning the necessity for new legislation which might be required to maintain privacy, we feel that a Congressional investigation addressing itself to all facets of the personal and corporate privacy question would be the appropriate forum for developing the requirements for any new legislation.

#### **Analyses of Responses Underway**

These are the Western Union positions in the Computer Inquiry. Now that all the Responses are filed, we await with interest the FCC's reaction to the issues which we have discussed. As of the March 9, 1968 filing date, responses from fifty-eight organizations have been received and must be evaluated by the Commission. These responses account for several thousand pages of testimony and represent a spectrum encompassing common carriers, equipment manufacturers, data processing service organizations, trade associations, educational institutions, major corporate users of computers and communications, and government agencies.

Concurrent with the FCC Internal evaluation activity, we at Western Union are also reading and analyzing the other responses. In addition to assessing the impact of the Inquiry upon our current business operations, we look forward to deriving useful information to aid us in continuing to serve the data communications public. ■

# Measurement and Analysis of Impulse Noise for Communications Circuits

By A. J. Seedman

Many studies made of impulse noise in communications systems indicate that the amplitude distribution curve follows a hyperbolic law. In practice, measurements of impulse noise in communications circuits are made with an impulse counter which has inherent limitations which alter the form of the amplitude distribution curve. These limitations are overcome in a new technique of measurement and analysis proposed by Western Union. Measurements of noise made on long distance circuits are used to derive an empirical equation of the form  $y = ax^b$ . The equation shows that a rate of 90 counts/half hour can be taken as the criterion; and the shape of the amplitude distribution curve can be defined by measuring the 90 count level and a few points above and below this level. The analysis technique leads to a system impulse noise map which can be used to locate noisy areas in a circuit and also to predict impulse noise for any route considered in circuit layout.

While error-free communication is virtually unobtainable in communications systems, great strides have been made in reducing the causes of one source of error, impulse noise. Western Union recognizes the need to reduce impulse noise in high speed data transmission and consequently has conducted a survey of the noise at numerous transmission facilities. From this study a new technique of analysis has been developed which can be applied to the construction of an impulse noise map, which can be used to more readily identify

the critical areas of noise. This map will be located at the new Technology Center in Mahwah, N. J. It will provide a geographical display of the impulse noise between any two points in the system.

This article points out the fact that a 3 point measurement of impulse noise satisfactorily defines the amplitude distribution. An empirical equation derived from the test data validates the fact that 3 points, properly selected, are sufficient to determine the knee of the curve of amplitude distribution.

## Impulse Noise

Impulse noise may be defined as a series of isolated pulses of very short duration. The component frequencies are so phased, with respect to each other, that their amplitudes add arithmetically at the instant of occurrence of the pulses. Impulse noise reaching a receiver may have pulse widths from microseconds to full bit widths, depending on where the noise was introduced and the modifying effects of the transmission circuit.

In practice a signal becomes an impulse when it is received as an isolated short burst. The duration of an impulse is short compared with receiver response time or with the reciprocal of the limiting receiver filter bandwidth.

The time and frequency domain, or spectrum, of an impulse are shown in Figs. 1a and 1b respectively.

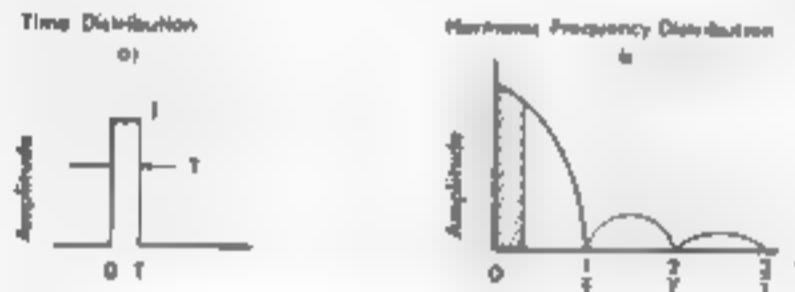


Figure 1—Representation of Time and Frequency Distributions of a Direct Impulse

The spectrum of an impulse has a  $\frac{\sin x}{x}$  envelope, but in the narrow region of interest the envelope is virtually flat. A low-duty-cycle pulsed signal is treated as an impulse, if it is received within a narrow band which is small compared to  $\frac{1}{T}$ , the reciprocal of pulse duration, but large compared to the pulse repetition frequency.

Unfortunately, the causes of impulse noise are quite difficult to identify. Sharp isolated peaks occur at times when the many components of different frequencies occur in phase. Also, singularly, each component may not be objectionable, but when in phase, a large spike may occur. The source of the interfering signals may be complex; that is, noise components from several sources may be additive in phase.

## Impulse Noise Counter

Impulse noise in communications circuits, is measured usually as a count of errors per bits transmitted. In a recent study by Western Union, a less sophisticated but direct approach was used. The count of impulses per unit time, at preset amplitudes, was measured with an impulse noise counter.

This method required only the one instrument, while the error count method requires several costly instruments. The impulse noise counter is the most popular method, since standards for impulse noise have been established, which are based on counts per unit time. Manufacturers specify the performance of their equipment in impulse noise counts per unit time at a given level.

The Northeast Electronics Model TTS-58A Impulse Noise Counter, used by Western Union to measure the impulse noise in the test circuits, gives, at best, only an approximation of the actual impulse noise. The maximum rate at which the counter will operate is limited by its electro-mechanical counters. After a count is registered, a reset interval of about 60 milliseconds is required before another count can be registered. The total set and reset cycle of a counter is about 100 milliseconds, thus limiting the counter to a maximum count of 10 counts per second.

These factors have been considered in the design of the impulse counter which represents the best compromise to approximate the "effects" of impulse noise and thus is accepted as a standard of sorts. The inherent limitations of the instrument may be partially overcome by ensuring that the rate of 300 counts per minute, (50% safety factor), is not exceeded.

When the inherent limitations of the impulse noise counter are overcome, the impulse noise amplitude distribution curve for most circuits appears to follow the hyperbolic form. The power function, later derived empirically from the measured data, closely resembles the hyperbola except for the skew as  $x$  increases. At this point the limitations of the count rate cause the curve to appear hyperbolic. As the sensitivity of the instrument is increased, it should continue to count at an increasingly higher rate; but when the maximum count rate of the instrument is reached, the ability to register all impulses is reduced. As shown in Figure 2, the curves of count per minute as a function of level, all go asymptotic around 50 counts

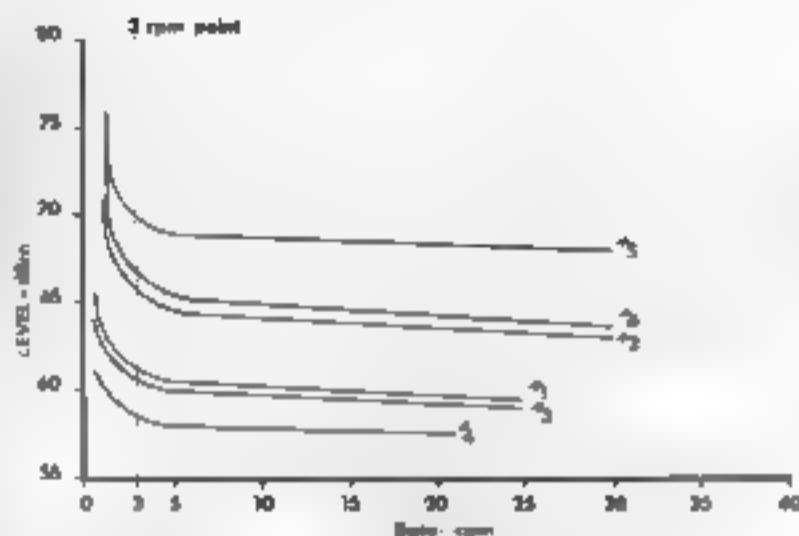


Figure 2—Amplitude Distribution of Impulse Noise

per minute, so the limitations of the instrument are essentially overcome and do not grossly affect our test data. Furthermore, this is unimportant since at the extremes the circuit is either errorless or unusable.

In addition to counting the number of impulses detected at various preset levels, a chart recorder was used to determine the distribution of noise with respect to time.

The impulse counter has three electro-mechanical counters which allow examination of the noise spectrum in discrete amplitude steps giving a histogram presentation. The low level counter registers those impulses which exceed the level set for LO but are less than the mid-level setting. The mid-level counter will register those impulses which exceed the MID setting, but are less than HI. The hi-level counter will register all counts which exceed the level set for HI.

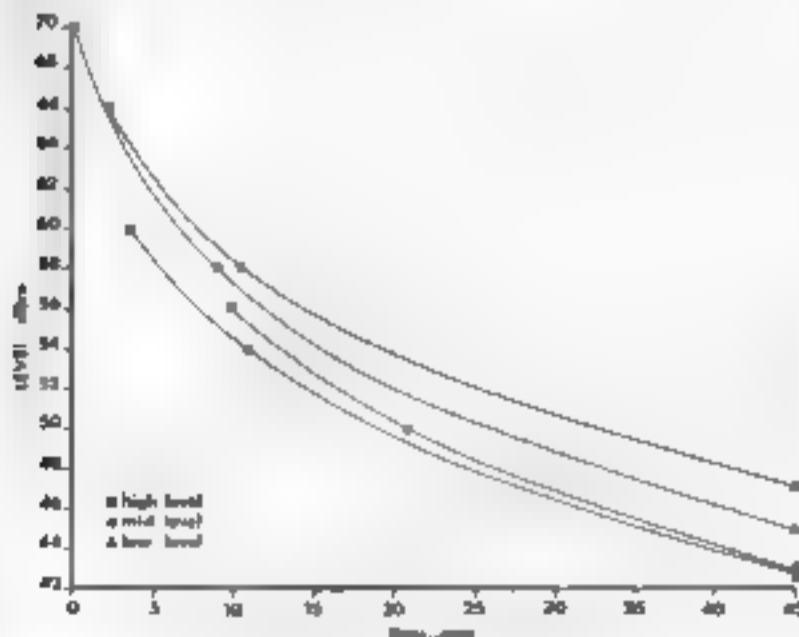


Figure 3—Test Data for Four Tests

## Tests

In a series of tests made on a microwave circuit the voice band filter was used to restrict the 3 dB bandwidth to the range of 660 Hz to 3.3 kHz. The data from these tests is plotted in a family of curves in Figure 3. Data was registered on 3 counters namely low-level (LO), mid level (MID) and high-level (HI) for each of four circuits.

The average of these four circuits was then plotted in Figure 4. Since the noise in a circuit is dependent upon traffic, and hence on the time of day, an average curve represents the circuit most effectively.

For convenience in analyzing the data an arbitrary translation of the x-axis is made in Figure 4. Since the curves in Figure 3 appear to be asymptotic above 50 cpm, we shall confine our analysis to only those rates below 50 cpm. The translation of x-axis is accomplished by determining that value of level (in dBm\*) where the curve appears to be asymptotic; this is then called the zero reference or 0 dB on the y scale in Figure 4. The y or zero reference was chosen as 42 dBm. It follows that 10 dB is equivalent to 52 dBm and 20 dB is 62 dBm on Fig. 4. This translation of axis makes it possible to compare the impulse noise amplitude distribution curve to that of a well known mathematical equation

\*dBm (decibels above reference noise) is weighted circuit noise power in dB referred to 1mW (-30 dBm) which is 0 dBm. With C-message weighting, a 1mW 1 kHz tone will read -30 dBm and the same power with white noise randomly distributed over the passband of the voice filter will also read -30 dBm.

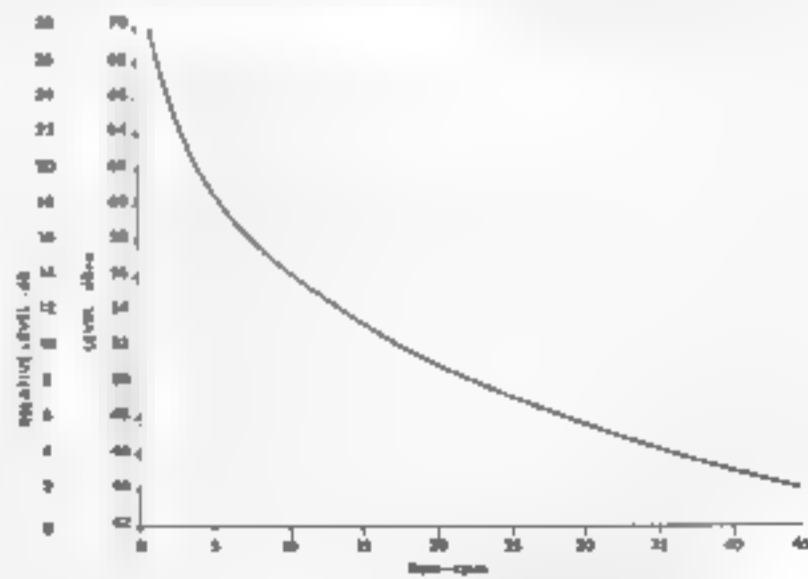


Figure 4—Average of Four Tests shown in Figure 3

From this average curve of Impulse Noise Amplitude Distribution in Figure 4, a table of  $x$  and  $y$  coordinates are obtained and are used to empirically derive an equation that defines the curve. From this, it is obvious that the impulse noise curve uniquely follows the curve for a power series. The argument for a hyperbolic distribution is often found in the literature, and we agree that this is indeed valid; but if we confine our study to an area of particular interest around the threshold of receiver sensitivity, we will show the validity of the power series definition.

The method described in the following example is that of curve fitting where we find the equation for a curve that most nearly fits our data. The equation empirically derived will be in terms of the coordinates established after translation of the  $x$ -axis, hence the procedure is not reversible. Given the equation we cannot define the curve in terms of dBm vs cpm without knowing what level in dBm is called the 0 dB reference. But this is not important at this point, we are interested in finding an equation to define impulse noise amplitude distribution first. Later, it will be shown that by knowing a mathematical definition of impulse noise in a system, we can use this knowledge to simplify the interpretation of data obtained from measurements.

The characteristics of impulse noise appear to be complete randomness. There are so many variables involved in attempting to analyze the problem analytically that it is better to do so empirically. The Western Union technique consists first of obtaining a set of observed values and then trying to define these values by plotting them on some coordinate paper and drawing a curve through the plotted points. If the points, when plotted on rectangular coordinate paper, lie approximately on a straight line, we assume that the equation  $y = mx + b$  represents the relationship. To determine the constants  $m$  and  $b$ , the slope and the  $y$  intercept may be read off the graph or they may be calculated by solving two linear equations for  $m$  and  $b$  obtained by substituting the coordinates of two points on  $y = mx + b$ .

Our data does not represent a straight line, so we can try some other form such as an algebraic polynomial, an exponential, a power function, etc. We would expect to find that the data will fit a curve of a form similar to a hyperbola. A curve fitted to the exponential form was chosen, as explained in the following section.

### Empirical Equation

If we take the common logarithm of the coordinates  $x$  and  $y$ , in Figure 4 we construct Table I,  $\mu = \log x$ ,  $\nu = \log y$ . When these points  $x$  and  $y$  are plotted on semilogarithmic paper, they tend to lie along a straight line. This line may be assumed to be of the form of equation  $y = ae^{\mu}$ .

TABLE I

$x$	$\mu$	$\log x$	$y$	$\nu$	$\log y$
2		.301	22.5	1.352	
4		.402	19.5	1.297	
6		.477	17.5	1.243	
8		.500	15.9	1.201	
10		.500	14.5	1.161	
12		.520	13.5	1.124	
14		.540	12.5	1.090	
16		.560	11.5	1.061	
18		.595	10.5	1.025	
20		.601	10.0	1.000	
22		.632	9.1	.959	
24		.650	8.5	.929	
26		.675	7.5	.892	
28		.697	7.0	.845	
30		.717	6.5	.799	
32		.736	5.7	.756	
34		.751	5.1	.704	

If we divide the data into 2 groups taking  $2 \leq x \leq 16$  as Group I and  $18 \leq x \leq 34$  as Group II, we can determine an average  $x_i$  and  $x_{ii}$  and a corresponding  $\nu_i$  and  $\nu_{ii}$  for the two groups.

$$\text{They are: } x_i = 9 \quad \nu_i = 1.19 \\ x_{ii} = 26 \quad \nu_{ii} = 0.879$$

The slope of the line ( $k$ ) through these two average points is.

$$k = \frac{\nu_i - \nu_{ii}}{x_i - x_{ii}} = -0.0185$$

and the equation of the straight line is

$$\nu - \nu_i = k(x - x_i) \\ \nu - 1.191 = -0.0185(x - 9)$$

or

$$\nu = -0.0185x + 1.357.$$

This equation is of the form  $\nu = kx + L$  which is the general form of a straight line.

where

$$k = -0.0185 \text{ and} \\ L = \log a = 1.357.$$

Taking the anti log of both sides, we have

$$\begin{aligned} y &= a(10)^x \\ y &= 22.75(10) - 0.0185x \\ y &= 22.75(e^{0.0185x}) - 0.0185x \\ y &= 22.75e^{-0.0185x} \end{aligned}$$

Thus, we empirically find an exponential amplitude distribution for impulse noise measured in the test circuit

To further substantiate that an equation of the form  $y = ax^x$  applies, additional measurements were made of impulse noise on many other circuits in N.Y., Chicago, Dallas and San Francisco. These provided data (cpm) which, when plotted as a function of amplitude provided curves which appeared to be hyperbolic since they were asymptotic in  $x$  and  $y$ . However, they were not asymptotic at the same rate. Rather than change the scale, an equation was found to describe the curve. By well known methods of curve fitting, equations for each set of test data were empirically derived for the curve. Several tests provided data which fit an exponential curve  $y = ae^{bx}$ . This is a special case of the general form of a power series, where  $y = y$

The general form of the power series is

$$\sum_{n=0}^{\infty} a_n x^n = a_0 + a_1 x + a_2 x^2 + \dots + a_n x^n + \dots$$

which, for a finite number of terms, can be written as

$$y = ax^x$$

#### Evaluation Of Actual Circuits

That portion of the impulse noise amplitude distribution curve where the slope changes from maximum to minimum is of particular interest. This portion generally lies between 0 and 20 counts per minute. Within this range is found the point (3 cpm) which has been established as the reference standard for impulse noise, 90 counts per 30 minutes. Because the 3 cpm point is located uniquely at the knee of the curve, as shown in Fig 2, it provides the setting level for the mid-range (MID) counter, thus establishing the levels for the hi-range and lo-range counters

The following example describes how an actual circuit may be evaluated with the 3 point measurement.

#### Example:

Test data is plotted and a smooth curve is drawn, as shown in Figure 5. The measurements were made at a +7dB level point of a voice frequency channel, therefore, it is necessary to refer all levels back to the zero reference level point. The signal level at the input to the data modem is -8dBm and the transmission loss is 0dB

data signal level at modem input	8dBm
measurement point level	+7dB
<hr/>	
	15dBm0

Test data showed the reference standard level to be 64dBm. This is equivalent to -26dBm (64dBm - 90dB = -26dBm)

reference standard level	-26dBm
measurement point level	+7dB
<hr/>	
	-33dBm0

Thus, the signal-to-impulse noise ratio is

$$-15 \text{ dBm0} - (-33 \text{ dBm0}) = 18 \text{ dB}$$

therefore, the circuit is acceptable for a data set requiring a signal-to-impulse noise ratio of 18dB or less

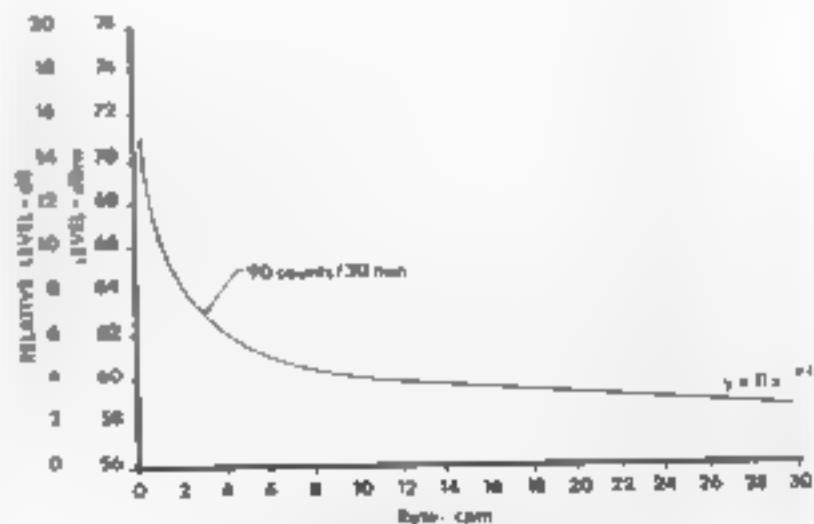


Figure 5—Average Curve for a Series of Different Circuits

## Knee Of The Curve

The knee of the curve is used to evaluate the amplitude distribution of impulse noise present in a circuit.

The impulse counter is most accurate when the level settings of its three counters are along the knee of the curve and not on a point of maximum or minimum slope. Because of this, the measurements of impulse noise should be made only within this range.

An average expression for impulse noise  $y = 10^{-4}$  was derived from a series of tests on different circuits and plotted on curve in Figure 5. In this case, the reference standard, 90 count/30 min. point, is at 63 dBm. It should be noted, that this point is centered on the knee of the curve.

## Significance

The method devised to analyze an actual circuit for impulse noise content is based on the analytical findings of many circuits tested. It has been shown that the 90 count per 30 minute point (3 cpm) on a curve of impulse noise amplitude distribution will always lie on or near the knee of the curve for a usable circuit. Thus, the curve would be approximated quite easily by locating the 90 count point, one point above it, and one point below it. The curve will go asymptotic at levels above the 90 count point and nearly asymptotic at some level below the 90 count point. We are interested in the knee of the curve and the near asymptote to the x-axis. Therefore, a measurement to define the knee and three points below the knee (lower levels) will provide adequate information to evaluate a circuit.

The knowledge that a plot of test data, from measurements made in a traffic environment with the impulse noise counter, will always follow the form of a power series—is highly significant. The operator can select the level settings of the instrument specifically to define the curve. Measurements made only around the reference standard level is likely to show low or zero counts at the HI and MID level settings. Such data is difficult to analyze. Test data that produces a power function curve can be readily compared with test data from other circuits. The plot itself, when it follows the proper curve, is sufficient verification of the validity of the measurements.

## Impulse Noise Mapping

A special technique for determining the critical areas of impulse noise has been under study at Western Union. If we assume a hypothetical communication system interconnecting 8 cities, A through H, as displayed in Figure 6, and indicate on the map the mileage plus the level at which the standard reference count was measured between any 2 points, we may quickly ascertain the most critical areas in the system.

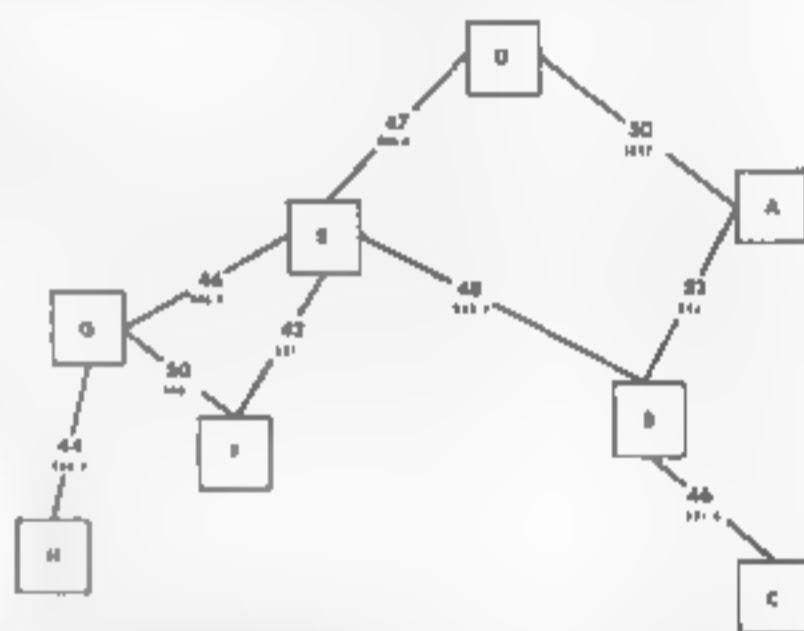


Figure 6—Hypothetical Communication System

Table II tabulates the individual mileage and noise reference standard level for those sections on the overall system.

TABLE II

ROUTE	Distance (Circuit MILES)	Reference Standard Level (dBm0Vd)
A-D-E	1382.9	47
A-E	1621.7	44
A-D-E-G	2617.8	44
A-E-G	2220.4	44
D-A-B-C	2056.7	44
D-E-B-C	2041.1	40
G-H	406.3	41
E-P	537.0	42
F-G	348.3	40
E-G	629.7	40
A-B	632.0	42
B-C	684.8	40
D-E	556.8	47
B-C	960.7	48
A-D	1032.1	50

## Conclusion

The significance of a mathematical expression for impulse noise in the traffic environment is two-fold. First, knowing that the 90 count/30 min. point will appear on the knee of a curve of amplitude distribution enables us to use a single point as a standard of comparison. If we choose a count rate which appears somewhere on the maximum or minimum slope of the curve, it would become exceedingly difficult to choose the proper level settings for the impulse noise counter when measuring a circuit. Secondly, we can take that portion of the curve that appears to be asymptotic in  $x$  and relate that level to the voice weighted rms white noise. It was found that the  $x$ -asymptote of the curve is about 12 dB higher than the rms white noise measured with a noise measuring set.

From the above we can establish confidence in impulse noise measurements. A quick plot of the counts registered by the LO, MID, and HI level counters will show if the knee of the curve is defined or if it is necessary to examine the impulse noise at higher or lower levels. By taking counts to define the knee and the  $x$  asymptote, the circuit

is evaluated. Care and understanding is essential in measuring impulse noise because of the completely random nature of the impulses. Measurements which specifically define a curve make the technique particularly useful in eliminating test data that even an expert is not capable of interpreting.

\* \* \*

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# Computer to Terminal

## Ringback Algorithm

by A. B. Wadler

### INTRODUCTION

In the design of an optimum algorithm (plan) which a computer can use in delivering messages through a circuit switching network, e.g. TELEX, a basic problem is to determine the times at which the computer should dial to make a connection with a particular terminal. A simple diagram of a typical system is shown in Fig. 1.

When the computer receives a message for the terminal it "dials out" attempting a connection. If the connection is made the message is delivered. However, if a "busy" is encountered, we must select the time for the next dial attempt. If this attempt fails, the next time must be selected and so on. Thus, the problem can be stated as—to devise an optimum algorithm which consists of a sequence of times ( $t_1, t_2, t_3, \dots$ ) at which we should dial, given that a "busy" was received at all previous dials. We note that  $t_1 < t_2 < t_3 \dots$

### CRITERIA FOR OPTIMALITY

Several criteria may be used to measure the optimality of the algorithm; however, two generic areas called the "cost of dialing" and the "cost of waiting" are most significant. Everytime we dial out we incur a cost, because we are utilizing time from the computer for the dial and we are utilizing

lines from the network. Thus, if "dial cost" is the prime consideration we should dial infrequently. However, this increases the "cost of waiting." Waiting cost consists of the cost of storing the message in the computer plus whatever cost we attribute to degrading service by having the customer wait for his message. Thus, if the cost of waiting is of prime importance, then we should dial out immediately; that is redial immediately after receiving a busy.

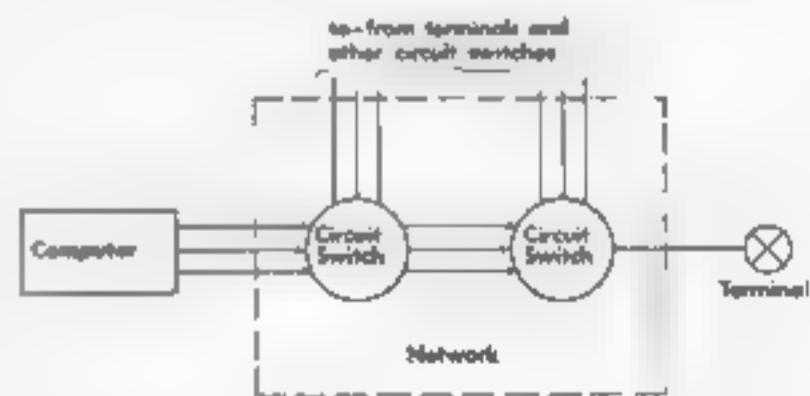


Figure 1—Simple Block Diagram of a Typical System.

It is obvious that these two costs conflict with one another; when we minimize the cost of one, we maximize the cost of the other. Thus, in this case "optimum" means minimizing the weighted sum of the two costs.

Let us examine this cost mathematically. When a busy is received, the busy could be due to either the network (its lines are "tied up") or the terminal to which we are dialing being busy (or both).

We define the network/terminal combination as the system and let  $SB(t_i)$  represent the event that the system is busy at time  $t_i$  and  $\bar{SB}(t_i)$  the event the system is not busy at  $t_i$ . Assume the first dial occurred at time  $t=t_0$ , the time a busy was encountered. At what time,  $t_1$ , should we attempt again? Putting this another way, at some time  $t_1 > t_0$  we wish to decide, based on our weighted cost criteria, whether to dial or to wait. The four possible outcomes from this decision, may be:

- (1) If we were to dial at  $t=t_1$  and the attempt were to be successful, we would save fu

ture dials and minimize waiting time. Let us call this saving  $S_D$ .

- (2) If we were to dial at  $t=t_1$  and the attempt were to be unsuccessful, we would incur the cost of one dial. Call this cost  $C_D$ .
- (3) If we were to wait (do not dial at  $t=t_1$ ) and the system happened to be free (the dial would have been successful), we would incur possible future dial costs (if the system becomes busy again) and incur increased wait time for the customer. Call this cost  $C_{WD}$  ( $WD$  = Not Dial).
- (4) If we were to wait and the system happened to be busy at  $t_1$ , we would save the cost of one dial =  $S_{WD}$ .

These four possible outcomes can be represented in the logic diagram in Figure 2.

The logic diagram was shown for  $t = t_1$  where  $t_1$  is any time greater than  $t_0$ . Obviously, the logic holds for any time  $t_1$  provided we have received "busys" at all previous dial times  $t_0, t_1, t_2, \dots, t_{1-1}$ .

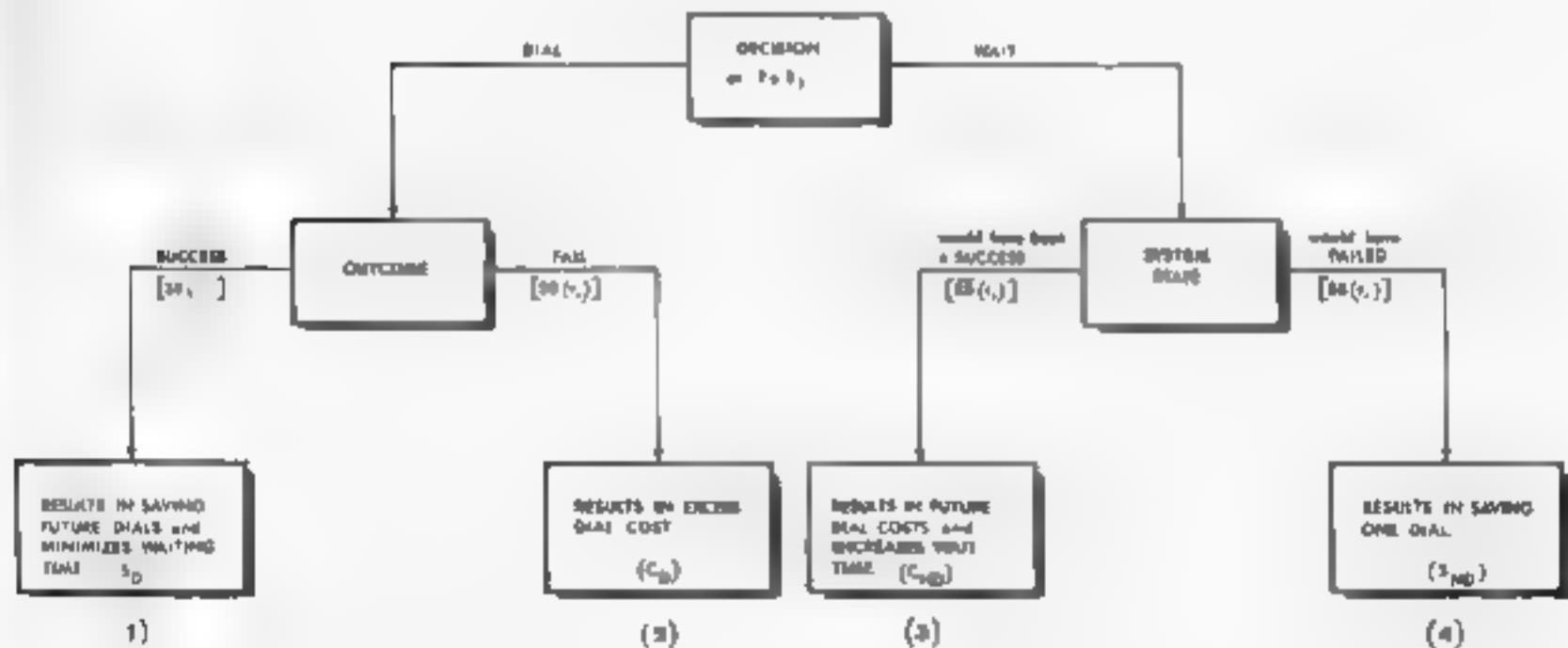


Figure 2—Four Possible Outcomes of the Decision "To Dial" or "To Wait" Ringback Algorithm.

## DIALOUT STRATEGY

Examination of our logic diagram of possible outcomes shows us that paths (1) and (4) yield what we have called net savings, whereas paths (2) and (3) yield what we have called costs. Since we do not know (before dialing) what the outcome of our decision will be, the best that we can do would be either to maximize the expected savings or to minimize the expected costs for our system. By either of these two strategies, we obtain the best "long run" or "on the average" system cost.

To illustrate the basic problem in a somewhat more simplified manner, suppose we hypothesize that the profit delivering a message is  $R$  dollars revenue less the costs of dialing, storage, handling, etc. This hypothesis is naive in that it neglects several cost elements which are not applicable to this problem. Thus, the profit on a message may be expressed as:

$$\$/(\text{Profit/msg}) = R - C_{\text{dial}} - C_{\text{storage}} - C_{\text{handling}} - \dots$$

For this simplified case, let us assume that the cost of storage is fixed, independent of how long the message has been stored. This assumption implies that speed of service is of no value and that the storage medium is not required for other messages. With this assumption in mind, we note that all of the terms in the above equation are constant with the exception of the accrued cost for having dialed. We group all the terms, other than  $C_0$ , and define the "Value" ( $V$ ) for getting a message delivered.  $V$  is independent of time because of the assumptions made.

Now, we adopt a particularly simple strategy which says "wait until the probability of getting through, times the value of getting through exceeds the cost of dialing,  $C_0$  — then dial". This probability can be shown in Figure 3.

Suppose we model our system busy conditions such that the probability of the network being busy is a constant ( $r$ ) independent of dialout trials. We model our terminal as having a busy period (holding time) which is exponentially distributed with a mean of  $T_b$ . Also, the arrival of messages to and from the terminal is random (Poisson distributed) with a mean interarrival time of  $T_A$ . The terminal utilization  $\rho$  is then  $\rho = T_b/T_A$ . Using this strategy,

the time for the first dial may be expressed as:

$$t_1 = T_b \log \frac{\rho(1-r)(1-\rho)}{\rho(1-r)+r][(1-\rho)-C_0/V(1-r)]} \quad (1)$$

All subsequent dials should be set at equal time intervals ( $\Delta t$ ), which may be expressed as:

$$\Delta t = T_b \log \frac{\frac{\rho}{k} - \frac{k}{k(1-r)+r}}{\rho} \quad (2)$$

where

$$k = 1 - \frac{C_0}{V(1-r)}$$

Note that regardless of how long we wait to dial, the probability of finding the system free never exceeds  $(1-\rho)(1-r)$ , so that  $C_0/V$  must be less than this value. Thus, in Fig. 3, the point A is  $(1-\rho)(1-r)$ .

For any given conditions of terminal busy times and free times, we may evaluate the above expressions and we have thereby defined an optimum strategy for ringback. Unfortunately, the fact that  $V$ , the value assigned to a successful dialout, is truly time dependent (that is, it is a function of both how "long" the message is in the system and how much longer it will remain if we do not dial at this time), makes the simplified case somewhat unrealistic.

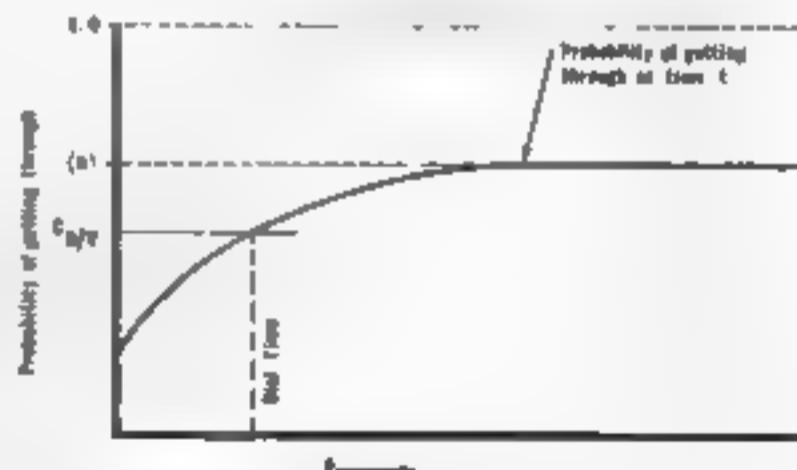


Figure 3—Probability of a successful Dialout vs. Time.

We now consider an analytical formulation based on the four cost criteria described in Figure 2 which hopefully takes into account this time dependency. At any decision time,  $t_i$ , we can say that we should dial out, if the expected savings, when we dial, exceeds the expected savings for waiting. Treating both the savings and cost as positive numbers, we see that:

$E$  savings if we dial

$$\begin{aligned} &= (\text{prob. of success})E[S_0] - \\ &\quad - (\text{prob. of failure})E[C_0] \\ &\approx \Pr[\bar{S}B(t_i)]E[S_0] - \Pr[SB(t_i)]E[C_0] \end{aligned} \quad (3)$$

$E$  savings if we wait

$$\begin{aligned} &= -(\text{prob. of success})E[C_{WD}] + \\ &\quad + (\text{prob. of failure})E[S_{WD}] \\ &\approx -\Pr[\bar{S}B(t_i)]E[C_{WD}] + \Pr[SB(t_i)]E[S_{WD}] \end{aligned} \quad (4)$$

Thus, we dial when

$$\begin{aligned} \Pr[\bar{S}B(t_i)]E[S_0] - \Pr[SB(t_i)]E[C_0] &\geq \\ &\approx -\Pr[\bar{S}B(t_i)]E[C_{WD}] + \Pr[SB(t_i)]E[S_{WD}] \end{aligned} \quad (5)$$

$$\text{Since } \Pr[\bar{S}B(t_i)] = 1 - \Pr[SB(t_i)] \quad (6)$$

Equation (5) can be written as

$$\begin{aligned} 1 - \Pr[SB(t_i)]E[S_0] - \Pr[SB(t_i)]E[C_0] &\geq \\ &\approx (1 - \Pr[SB(t_i)])E[C_{WD}] + \Pr[SB(t_i)]E[S_{WD}] \end{aligned} \quad (7)$$

After some algebraic manipulation, this inequality (7) can be re-written as (8)

$$\Pr[SB(t_i)] < \frac{E[S_0] + E[C_{WD}]}{E[S_0] + E[C_0] + E[S_{WD}] + E[C_{WD}]} \quad (8)$$

We dial when equation (8) is true.

Thus, given that we have been unsuccessful up to time  $t_{i-1}$ , we begin computing  $\Pr[SB(t_i)]$  with increasing time, and we dial out only when this quantity just equals the right hand side of equation (8). If the attempt is successful, the game is over. If not, we reconstruct the inequality for  $t_{i+1}$  and start counting from  $t_i$ , etc.

Before proceeding, for simplicity let us set

$$\frac{E[S_0] + E[C_{WD}]}{E[S_0] + E[C_0] + E[S_{WD}] + E[C_{WD}]} \triangleq \lambda \quad (9)$$

where certainly  $0 \leq \lambda \leq 1$ .

A few remarks about  $\lambda$  are in order. We note that  $\lambda$  is a function of the expected values of several random variables. That is, the values of  $S_0$  and  $C_{WD}$  require the knowledge of how many more dials are required, if we do not get through at our present decision time. Similarly, it also requires the knowledge of how long we have to wait until we finally make the connection etc. These elements are random variables in the sense that they cannot be computed with any certainty, thus we use the expected values of these variables. In addition, not only are these quantities random variables but their expected values are time dependent. That is, the values of  $E(S_0)$  and  $E(C_{WD})$  (and therefore,  $\lambda$ ) are functions of that point in time where these elements are computed. Thus, we should write  $\lambda = \lambda(t)$ . With this, we shall assume (for the moment) that we can compute as functions of time both  $\Pr[SB(t)]$  and  $\lambda(t)$  and construct the desired algorithm in Figure 4.

#### Iterative Strategy

The algorithm required no "a priori" time sequences ( $t_1, t_2, t_3, \dots$ ) but rather used an inequality (8) by which these times can be determined (one at a time). This strategy requires the computation, as functions of time, of  $\Pr[SB(t)]$  and of  $\lambda(t)$ . The former element can be computed as will be shown in a later section. However, the computation of  $\lambda(t)$  proved impossible thus making the algorithm unfeasible (although interesting). To show this, let us examine  $\lambda(t)$  at some specific time —say  $t_i$ , and look at one element of  $\lambda(t)$  say  $E[C_{WD}]$ .  $E[C_{WD}]$  as we recall, is the expected cost

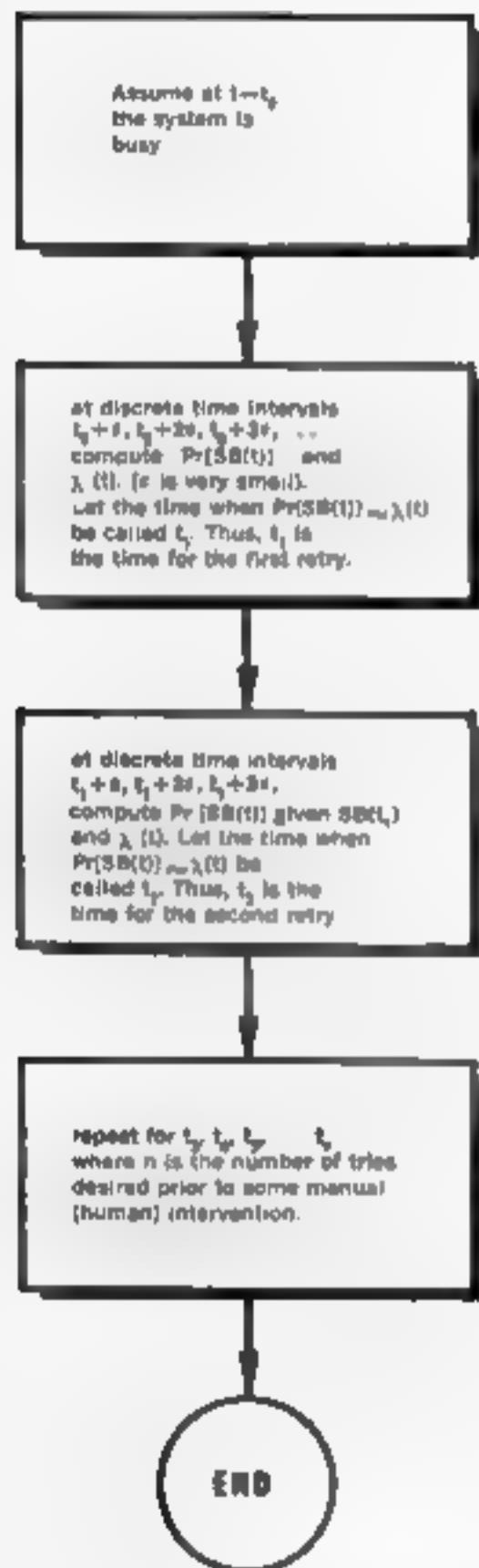


Figure 4—Algorithm using the Inequality (10).

resulting from future dials we must make, plus the expected cost of additional wait time given, we did not dial at  $t_i$ —whereas, if we had, we would have made a connection. Calculating the expected cost of future dials involves calculating the expected number of future dials. In order to do this, however, the future dial times must be known. That is, in order to calculate  $E[\text{Number of future dials required to get out}]$  (assuming we are not yet out at  $t_i$ ) requires that we know at what times  $t_{i+1}, t_{i+2}, \dots$  we are going to make future attempts. However at  $t_i$ , we have not yet determined the future dial times, and therefore cannot compute  $\lambda_i(t_i)$ . Thus, this approach appears to be unfeasible and a simpler, but somewhat less powerful, approach was implemented. This approach can be called an iterative strategy (trial and error).

We “apriori” select a large (but necessarily finite) number of possible sequences. That is, we pick  $M$  sequences  $S_1, S_2, \dots, S_M$  where  $S_i$  is defined by  $(t_{i1}, t_{i2}, t_{i3}, \dots, t_{iN})$ , the times we attempt to dial, assuming we have failed on all previous

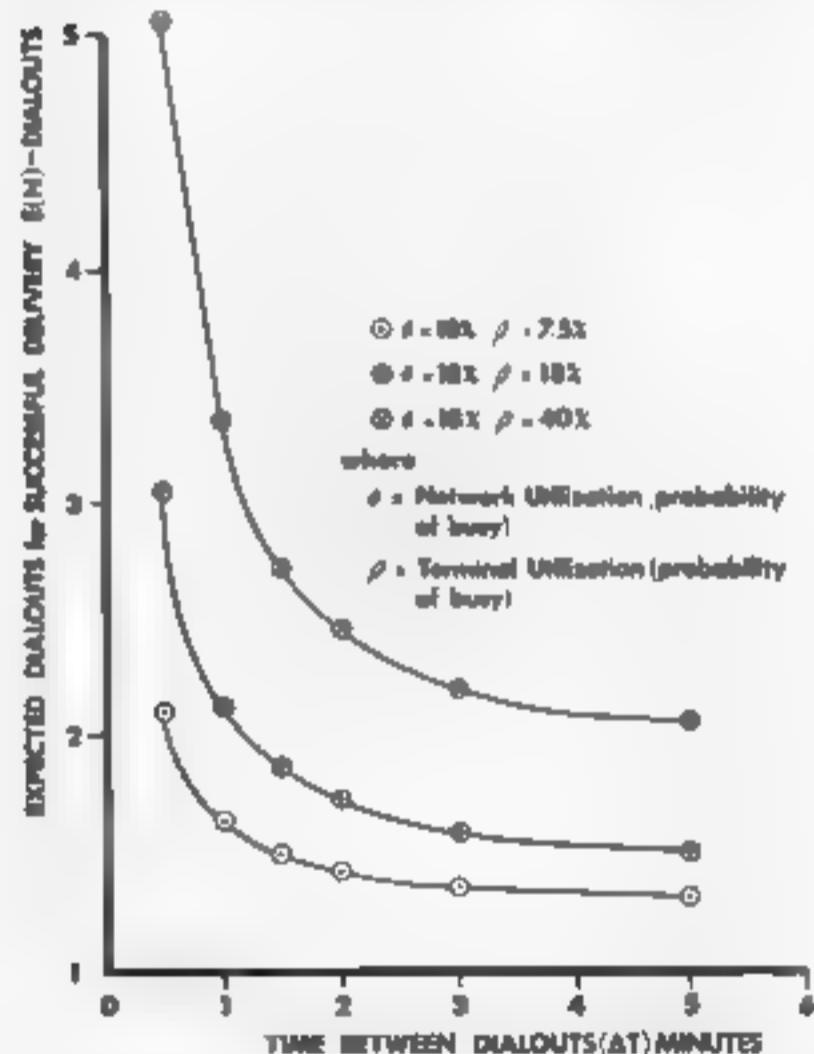


Figure 5—Plot of Expected Number of Dialouts to successful Delivery vs. Time Between Dialouts.

times. For each sequence  $S_i$  we compute the expected number of dials required to make the connection  $E[N]$ , and the expected time (measured from  $t=0$ ) the connection will be made  $E[T_w]$ . We "weight" the two by defining the expected cost of this sequence by:  $E[C] = WE[N] + (1-W)E[T_w]$  where  $W(0 \leq W \leq 1)$  is the weighting factor. The optimum sequence is then the sequence whose  $E[C]$  is a minimum.

### Some Typical Results

The latter algorithm was placed on a computer and used to evaluate several proposed ringback schemes for ISCS PHASE 0 where the average terminal holding time is estimated as 1.5 minutes. For illustrative purposes the results of a series of runs are shown in Figures 5 and 6. For these runs a fixed network utilization of 18% was used.

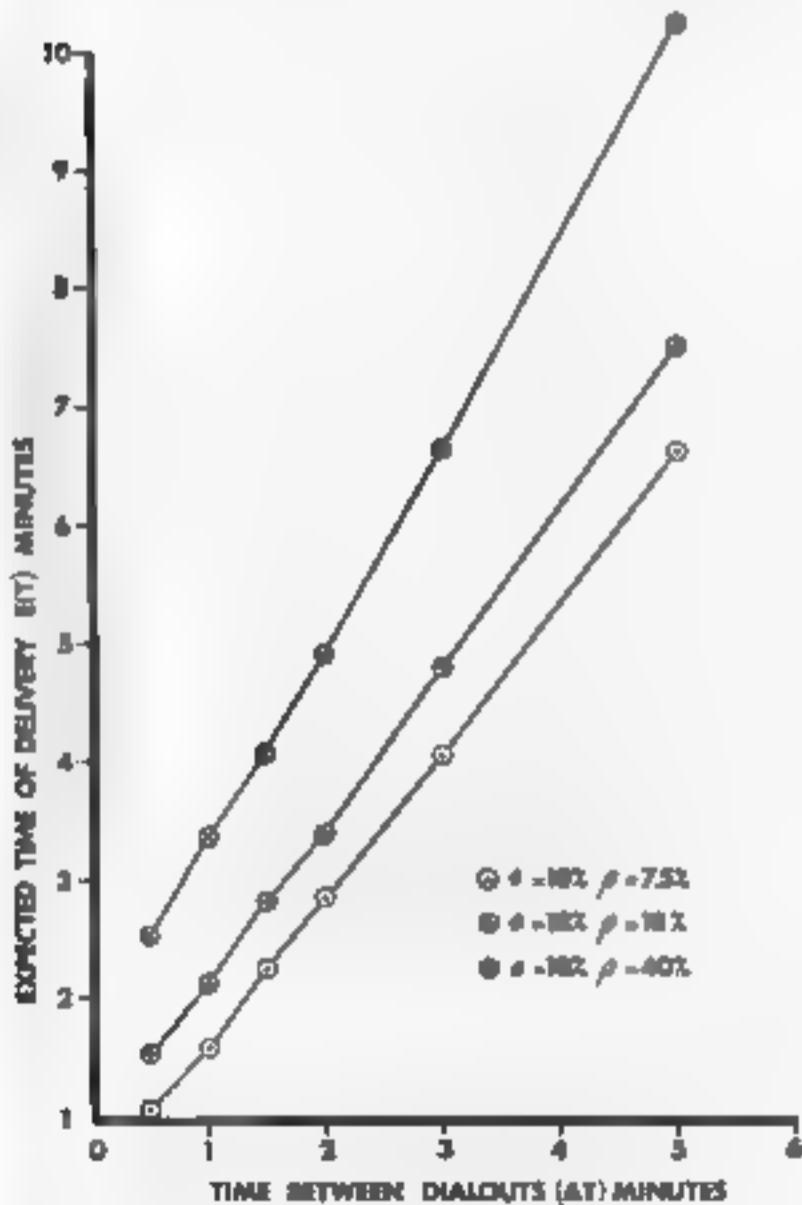


Figure 6—Plot of Time of Delivery vs. Time Between Dialouts.

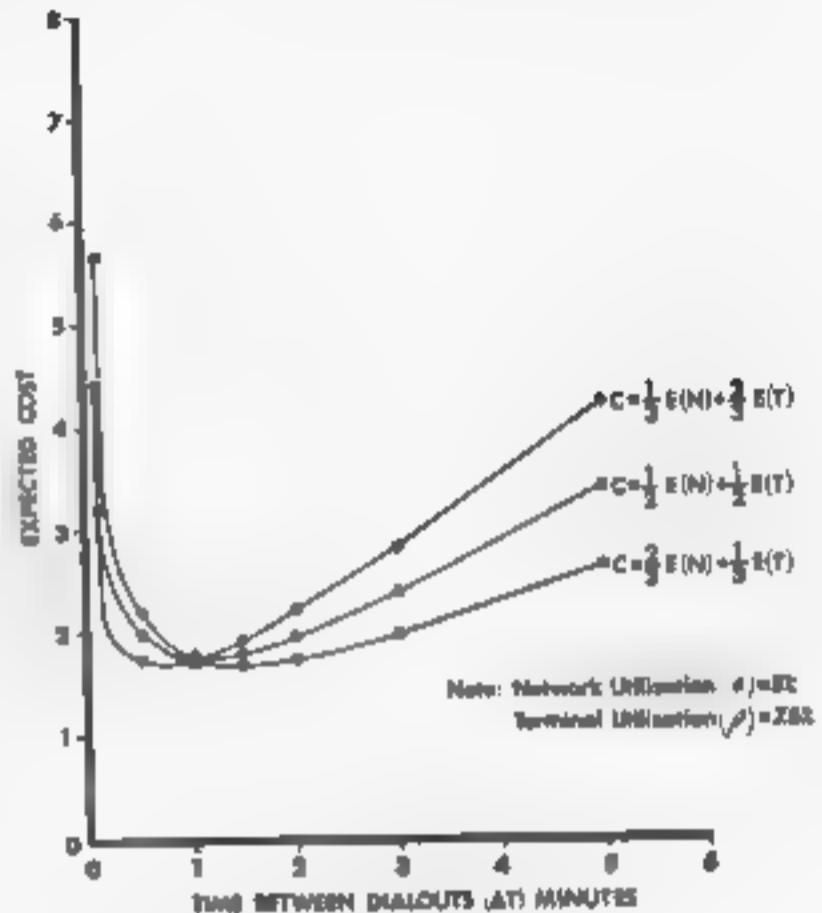


Figure 7—Plot of Expected Cost of Delivery vs. Time Between Dialouts.

Also the ringback time sequences used were such that the time between dialouts was constant for each run. As seen the intervals selected were 0.5, 1.0, 1.5, 2.0, 3.0 and 5.0 minutes. For each time interval three runs were made with terminal utilizations of 7.5%, 18% and 40%. Figure 5 indicates the expected (average) number of dialouts required for a successful delivery as a function of the time interval. Figure 6 indicates the expected time the successful dialout will occur (as measured from the first unsuccessful one at  $t=0$ ).

Figure 7 shows the weighted cost as a function of the dialout interval for weighting factors ( $W$ ) of  $1/3$ ,  $1/2$  and  $2/3$ . Recall that  $E[C] = WE[N] + (1-W)E[T_w]$ .

## DERIVATIONS

We define the expected number of dials required to make a connection as  $E[N]$  and the expected time (measured from  $t_0=0$ ) we wait for a successful connection as  $E[T_w]$ . These two measures represent the significant elements of cost to be weighted. We "weight" the two by calculating the expected cost of any prespecified dialout sequence as

$$E[C] = W E[N] + (1-W) E[T_w] \quad (10)$$

where  $W$  is a constant ( $0 \leq W \leq 1$ ). The optimum sequence is that sequence where  $E[C] = \min$ . We shall now describe the analytics for the calculations of  $E[N]$  and  $E[T_w]$  given a certain sequence  $(t_1, t_2, \dots)$ .

For those readers not familiar with probability theory, some of its basic concepts will be provided to assist in the understanding of this section. Some knowledge of elementary calculus is assumed.

### Probability Theory

If we have two events  $A$  and  $B$ , we define  $Pr[A \cup B]$  as the probability that either  $A$  or  $B$  or both events occur. Also,  $Pr[A \cap B]$  is the probability that both events  $A$  and  $B$  occur. The conditional probability  $Pr[B|A]$  denotes the probability of  $B$  occurring given that event  $A$  has occurred. The basic relationships linking these concepts are:

$$Pr[A \cup B] = Pr[A] + Pr[B] - Pr[A \cap B] \quad (11)$$

$$Pr[B|A] = \frac{Pr[A \cap B]}{Pr[A]} \quad (12)$$

With these elementary concepts as a guide we proceed to our problem, the calculations of  $E(N)$ , the expected number of dials required in order to make a connection, and  $E(T_w)$ , the expected time for the connection. Both of these values to be computed given a dialout sequence denoted as  $(t_1, t_2, t_3, \dots)$ .

Every time we dial we either get a busy or get through. For the  $i^{\text{th}}$  dial out (DO) occurring at  $t=t_i$  ( $t_0=0$ ), we let  $SB(t_i)$  be the event of getting a busy (as before). Let  $X_i$  = the probability of getting out, for the first time, at exactly the  $i^{\text{th}}$  DO given  $SB(t_0)$ .

Then

$$E(N) = 1X_1 + 2X_2 + 3X_3 + \dots + MX_M - \sum_{i=1}^{i=M} iX_i \quad (13)$$

$$E(T_w) = t_1X_1 + t_2X_2 + t_3X_3 + \dots + t_MX_M - \sum_{i=1}^{i=M} t_iX_i \quad (14)$$

(where at the  $M^{\text{th}}$  try we submit the message to manual intervention, thus  $X_i=0$  for all  $i > M$ ).

From its definition we can express  $X_i$  as,

$$X_i = \frac{Pr[\bar{SB}(t_i) \cap SB(t_{i-1}) \cap SB(t_{i-2}) \cap \dots \cap SB(t_1) \cap SB(t_0)]}{Pr[SB(t_0)]} \quad (15)$$

From Equation (12), we can write

$$X_i = \frac{Pr[\bar{SB}(t_i) \cap SB(t_{i-1}) \cap SB(t_{i-2}) \cap \dots \cap SB(t_1) \cap SB(t_0)]}{Pr[SB(t_0)]} \quad (16)$$

For simplicity let  $\tilde{SB}(t_i) \triangleq SB(t_i) \cap SB(t_{i-1}) \cap \dots \cap SB(t_1) \cap SB(t_0)$ . That is,  $\tilde{SB}(t_i)$  is the event that the system was busy at all dials up to and including the  $i^{\text{th}}$ .

Utilizing this nomenclature (16) is

$$X_i = \frac{Pr[\bar{SB}(t_i) \cap \tilde{SB}(t_{i-1})]}{Pr[SB(t_0)]} \quad (17)$$

From (12) again (16) may be expressed as

$$X_i = \frac{Pr[\bar{SB}(t_i) \cap \tilde{SB}(t_{i-1})] \cdot Pr[\tilde{SB}(t_{i-1})]}{Pr[SB(t_0)]} = \frac{Pr[\bar{SB}(t_i) \cap \tilde{SB}(t_{i-1})] \cdot \frac{Pr[\tilde{SB}(t_{i-1})]}{Pr[SB(t_0)]}}{Pr[SB(t_0)]} = \frac{Pr[\bar{SB}(t_i) \cap \tilde{SB}(t_{i-1})] \cdot \frac{Pr[\tilde{SB}(t_{i-1})]}{Pr[SB(t_0)]}}{Pr[SB(t_0)]} \quad (18)$$

Continuing this formulation (15) can be expressed as,

$$X_i = \Pr[\bar{SB}(t_i) | \bar{SB}(t_{i-1})] \cdot \\ \cdot \Pr[SB(t_{i-1}) | \bar{SB}(t_{i-1})] \cdots \Pr[SB(t_2) | \bar{SB}(t_1)] \cdot \\ \cdot \Pr[SB(t_1) | SB(t_0)] \quad (19)$$

Or finally;

$$X_i = (1 - \Pr[SB(t_i) | \bar{SB}(t_{i-1})]) \cdot \\ \cdot \prod_{j=1}^{i-1} \Pr[SB(t_j) | \bar{SB}(t_{j-1})] \quad (20)$$

where

$$\prod_{i=1}^j f(i) = f(1) \cdot f(2) \cdot f(3) \cdots f(j) \text{ the cumulative product.}$$

Thus the solution of  $X_i$  (and therefore  $E(N)$  and  $E(T_w)$ ) involves the solution of  $\Pr[SB(t_i) | \bar{SB}(t_{i-1})]$ ,  $i=1,2 \dots$ . That is, the probability the system is busy at  $t_i$  given it has been busy at all previous dial times.

For simplicity let

$$y(t_i) \triangleq \Pr[SB(t_i) | \bar{SB}(t_{i-1})] \quad (21)$$

Thus,

$$X_i = [1 - y(t_i)] \prod_{j=1}^{i-1} y(t_j) \quad (22)$$

Examining  $y(t_j)$  we see that the event  $SB(t_j)$  (getting a busy on the  $j^{\text{th}}$  DO) can occur if either (or both) the terminal or the network is busy.

Let  $TB(t_j)$  = the event the terminal is busy at  $t_j$  (the  $j^{\text{th}}$  DO).

Let  $NB(t_j)$  = the event the network is busy at  $t_j$ .

Therefore

$$y(t_j) = \Pr[TB(t_j) \cup NB(t_j) | \bar{SB}(t_{j-1})] \quad (23)$$

which, from (11) is:

$$y(t_j) = \Pr[TB(t_j) | \bar{SB}(t_{j-1})] + \\ + \Pr[NB(t_j) | \bar{SB}(t_{j-1})] - \\ - \Pr[TB(t_j) \cap NB(t_j) | \bar{SB}(t_{j-1})] \quad (24)$$

Now we make some reasonable assumptions regarding the network. We assume the DO intervals are long enough so that the event  $NB$  is independent of time and of all previous events. That is, any time we examine the network, the probability of it being busy is constant, the constant being the average utilization of the network ( $\triangleq r$ ).

Under these assumptions,

$$\Pr[NB(t_j) | \bar{SB}(t_j)] = r$$

and since  $NB$  and  $TB$  are independent

the last term of (24) is

$$r \Pr[TB(t_j) | \bar{SB}(t_{j-1})]$$

Thus (24) can be expressed as:

$$y(t_j) = \Pr[TB(t_j) | \bar{SB}(t_{j-1})](1 - r) + r \quad (25)$$

Since  $r$  is presumed known it remains only to solve for  $\Pr[TB(t_j) | \bar{SB}(t_{j-1})]$ ; that is the probability that the terminal is busy at  $t_j$  given that the system has been busy at all previous DO times.

We note that the expression  $\Pr[TB(t_j) | \bar{SB}(t_{j-1})]$  is a function of two times  $t_j$  and  $t_{j-1}$ . For simplicity, thus define;

$$z(t_j, t_{j-1}) \triangleq \Pr[TB(t_j) | \bar{SB}(t_{j-1})] \quad (26)$$

making

$$y(t_j) = [z(t_j, t_{j-1})](1 - r) + r \quad (27)$$

As a review the linkages to the solution are:

$$z(t_j, t_{j-1}) \rightarrow y(t_j) \rightarrow X_i \rightarrow E(N) \\ \rightarrow E(T_w)$$

"All" that remains now is to solve for  $z(t_j, t_{j-1})$ . We begin by first examining  $z(t_j + \epsilon, t_{j-1})$  where  $\epsilon$  is an extremely short time interval. Now,  $z(t_j + \epsilon, t_{j-1})$  is the probability the terminal is busy at  $t_j + \epsilon$  given it was busy at  $t_{j-1}$  and at all previous times. The event  $TB(t_j + \epsilon)$  could occur two ways.

- (i) the terminal was busy at  $t_j$  and remained busy at  $t_j + \epsilon$ . Or,
- (ii) the terminal was free at  $t_j$  and went busy during the interval  $\epsilon$ .

Since we can make the interval  $\epsilon$  as small as we wish, we ignore any multiple state changes occurring during the interval

Taking these two possibilities into account we can write for

$$\begin{aligned} z(t_j + \epsilon, t_{j-1}) &= \\ &= \Pr[TB(t_j + \epsilon) | TB(t_j)] \cdot \Pr[TB(t_j) | \bar{SB}(t_{j-1})] + \\ &\quad + \Pr[TB(t_j + \epsilon) | \bar{TB}(t_j)] \cdot \Pr[\bar{TB}(t_j) | \bar{SB}(t_{j-1})] \end{aligned} \quad (28)$$

In order to proceed, we must now define the terminal busy and free time distribution

We assume that the length of time a terminal remains busy (for one connection) is a random variable, which is exponentially distributed with an average length  $T_b$ .

Under these assumptions

$$\begin{aligned} \Pr[TB(t_j + \epsilon) | TB(t_j)] &= \\ &= e^{-\epsilon/T_b} \approx 1 - \epsilon/T_b \text{ for } \epsilon/T_b \ll 1 \end{aligned} \quad (29)$$

To determine the free time distribution (the length of time the terminal is free between connections) we note that if the time between messages arriving at the terminal is high relative to the mean busy time, the time the terminal is free is approximately the time between message arrivals or the interarrival time. Note that this assumption is valid under "low" terminal utilizations. Assuming the interarrival time is random (the message arrival rate is Poisson distributed) with an average time between arrivals of  $T_a$  yields.

$$\begin{aligned} \Pr[TB(t_j + \epsilon) | \bar{TB}(t_j)] &= \\ &= 1 - e^{-\epsilon/T_a} \approx \epsilon/T_a \text{ for } \epsilon/T_a \ll 1 \end{aligned} \quad (30)$$

Note that  $T_b/T_a \triangleq \rho$  the average terminal utilization. Combining (30) and (29) with (28) yields

$$\begin{aligned} z(t_j + \epsilon, t_{j-1}) &= (1 - \epsilon/T_b) \Pr[TB(t_j) | \bar{SB}(t_{j-1})] + \\ &\quad + (\epsilon/T_a) \Pr[\bar{TB}(t_j) | \bar{SB}(t_{j-1})] \end{aligned} \quad (31)$$

or

$$\begin{aligned} z(t_j + \epsilon, t_{j-1}) &= (1 - \epsilon/T_b) \Pr[TB(t_j) | \bar{SB}(t_{j-1})] + \\ &\quad + (\epsilon/T_a) (1 - \Pr[TB(t_j) | \bar{SB}(t_{j-1})]) \end{aligned} \quad (32)$$

Since from (26)  $\Pr[TB(t_j) | \bar{SB}(t_{j-1})] \triangleq z(t_j, t_{j-1})$

$$\begin{aligned} z(t_j + \epsilon, t_{j-1}) &= (1 - \epsilon/T_b) z(t_j, t_{j-1}) + \\ &\quad + \epsilon/T_a (1 - z(t_j, t_{j-1})) \end{aligned} \quad (33)$$

or

$$\begin{aligned} z(t_j + \epsilon, t_{j-1}) &= \epsilon/T_a + z(t_j, t_{j-1}) - \\ &\quad - z(t_j, t_{j-1}) (\epsilon/T_b + \epsilon/T_a) \end{aligned} \quad (34)$$

Subtracting  $z(t_j, t_{j-1})$  from both sides yields

$$\begin{aligned} z(t_j + \epsilon, t_{j-1}) - z(t_j, t_{j-1}) &= \\ &= \epsilon/T_a - z(t_j, t_{j-1}) (\epsilon/T_b + \epsilon/T_a) \end{aligned} \quad (35)$$

Dividing both sides by  $\epsilon$  and setting in the limit  $\epsilon \rightarrow 0$ , yields the following differential equation.

$$\frac{dz(t_j, t_{j-1})}{dt} = \frac{1}{T_a} - z(t_j, t_{j-1}) (1/T_b + 1/T_a) \quad (36)$$

$$\text{Now } \frac{1}{T_b} + \frac{1}{T_a} \approx \frac{1}{T_b}$$

since we have assumed  $T_a \gg T_b$

Thus

$$\frac{dz(t_j, t_{j-1})}{dt} = \frac{1}{T_b} - z(t_j, t_{j-1}) \frac{1}{T_b} \quad (37)$$

The partial solution of (37) is given by,

$$z(t_j, t_{j-1}) = T_b/T_a - \theta e^{-\theta(t_j - t_{j-1})/T_b} \quad (38)$$

where  $\theta$  is a boundary condition which is solved for, by noting that

$$z(t_{j-1}, t_{j-1}) = T_b/T_a - \theta$$

$$\text{or} \quad \theta = T_b/T_a - z(t_{j-1}, t_{j-1}) \quad (39)$$

Thus the complete solution of  $z(t, t_{j-1})$  is

$$\begin{aligned} z(t_j, t_{j-1}) &= \\ &= T_b/T_a - [T_b/T_a - z(t_{j-1}, t_{j-1})] e^{-\theta(t_j - t_{j-1})/T_b} \end{aligned} \quad (40)$$

The "correctness" of this solution can be verified by differentiating (40) and reconstructing the original differential equation. Differentiating (40) yields

$$\frac{dz(t_j, t_{j-1})}{dt} = \frac{1}{T_b} [T_b/T_a - z(t_{j-1}, t_{j-1})] e^{-\theta(t_j - t_{j-1})/T_b} \quad (41)$$

But from (40)

$$\begin{aligned} &T_b/T_a - z(t_{j-1}, t_{j-1})] e^{-\theta(t_j - t_{j-1})/T_b} \\ &= T_b/T_a - z(t_j, t_{j-1}) \end{aligned} \quad (42)$$

Thus,

$$\begin{aligned} \frac{dz(t_j, t_{j-1})}{dt} &= (1/T_b) [T_b/T_a - z(t_j, t_{j-1})] \\ &= 1/T_a - \frac{z(t_j, t_{j-1})}{T_b} \end{aligned} \quad (43)$$

which is identical to (37) our starting equation.

Returning to our solution (40), it can be written as:

$$z(t_j, t_{j-1}) = \rho - [\rho - z(t_{j-1}, t_{j-1})] e^{-\theta(t_j - t_{j-1})/T_b} \quad (44)$$

It can be shown (see appendix) that

$$z(t_{j-1}, t_{j-1}) = Pr[TB(t_{j-1}) | \tilde{SB}(t_{j-1})] \quad (45)$$

can be written as:

$$z(t_{j-1}, t_{j-1}) = \frac{z(t_{j-1}, t_{j-2})}{[z(t_{j-1}, t_{j-2})(1-r) + r]} \quad (46)$$

Substituting (46) into (44) yields (finally)

$$\begin{aligned} z(t_j, t_{j-1}) &= \\ &= \left[ \rho - \frac{z(t_{j-1}, t_{j-2})}{[z(t_{j-1}, t_{j-2})(1-r) + r]} e^{-\theta(t_j - t_{j-2})/T_b} \right] e^{-\theta(t_{j-1} - t_{j-2})/T_b} \end{aligned} \quad (47)$$

We note that a closed form solution is not available. The solution for an interval  $(t_j, t_{j-1})$  depends on the solution for the previous interval  $(t_{j-1}, t_{j-2})$ . Thus what is required is the solution at the first interval which can then be inserted for the solution of the second which in turn is used for the third and so on.

Proceeding with the solution of  $z(t_1, t_0)$  and recalling that  $t_0 \triangleq 0$  we see from eq (38) that

$$z(t_1, t_0) = \frac{T_b}{T_a} - \theta e^{-\theta t_1/T_b} \quad (48)$$

where  $\theta_1$ , the boundary condition, can be derived by noting that,

$$z(t_0, t_0) = \frac{T_b}{T_a} - \theta_1 \quad \text{or} \quad \theta = \frac{T_b}{T_a} - z(t_0, t_0) \quad (49)$$

Thus,

$$z(t_1, t_0) = \frac{T_b}{T_a} - \left[ \frac{T_b}{T_a} - z(t_0, t_0) \right] e^{-\theta t_1/T_b} \quad (50)$$

or

$$z(t_1, t_0) = \rho - [\rho - z(t_0, t_0)] e^{-\theta t_1/T_b} \quad (51)$$

From our definition of  $z$  however (eq 26)

$$\begin{aligned} z(t_0, t_0) &= \Pr[TB(t_0) \cap SB(t_0)] \\ &= \Pr[TB(t_0) \cap SB(t_0)] \\ &\quad - \Pr[\overline{SB}(t_0)] \end{aligned} \quad (52)$$

Since the event  $SB(t_0)$  includes the event  $TB(t_0)$   $\{TB(t_0) \cap SB(t_0)\} = TB(t_0)$  we see that:

$$z(t_0, t_0) = \frac{\Pr[TB(t_0)]}{\Pr[\overline{SB}(t_0)]} \quad (53)$$

But  $\Pr[TB(t_0)] = p$  and

$$\begin{aligned} \Pr[SB(t_0)] &= \Pr[TB(t_0)] + \Pr[NB(t_0)] - \\ &\quad - \Pr[TB(t_0) \cap NB(t_0)] \\ &= p + r - pr = p(1 - r) + r \end{aligned} \quad (54)$$

Thus,

$$z(t_0, t_0) = \frac{p}{p(1 - r) + r} \quad (55)$$

and

$$z(t_1, t_0) = p - \left[ p - \frac{p}{p(1 - r) + r} \right] e^{-t_1/T_0} \quad (56)$$

Therefore, in summary we have the following equations:

$$E(N) = \sum_{i=1}^M iX_i \quad (13)$$

$$E(T_w) = \sum_{i=1}^M t_i X_i \quad (14)$$

$$X_i = \{1 - y(t_i)\} \prod_{j=i+1}^{j=t-1} y(t_j) \quad (22)$$

$$y(t_i) = [z(t_i, t_{i-1})][1 - r] + r \quad (27)$$

$$\begin{aligned} z(t_j, t_{j-1}) &= \\ &= p - \left[ p - \frac{z(t_{j-1}, t_{j-2})}{[z(t_{j-1}, t_{j-2})](1 - r) + r} \right] e^{-t_{j-1}/T_0} \end{aligned} \quad (47)$$

$$z(t_1, t_0) = p - \left[ p - \frac{p}{p(1 - r) + r} \right] e^{-t_1/T_0} \quad (56)$$

The computer program shown in Fig. 8 was used to compute the above; the end resulting, for each sequence tried,  $E(C) = W E(N) + (1 - W) E(T_w)$ .

Note that we have limited the number of tries to  $M$ , where on the  $M^{\text{th}}$  try, the message is sent to a local terminal for manual intervention

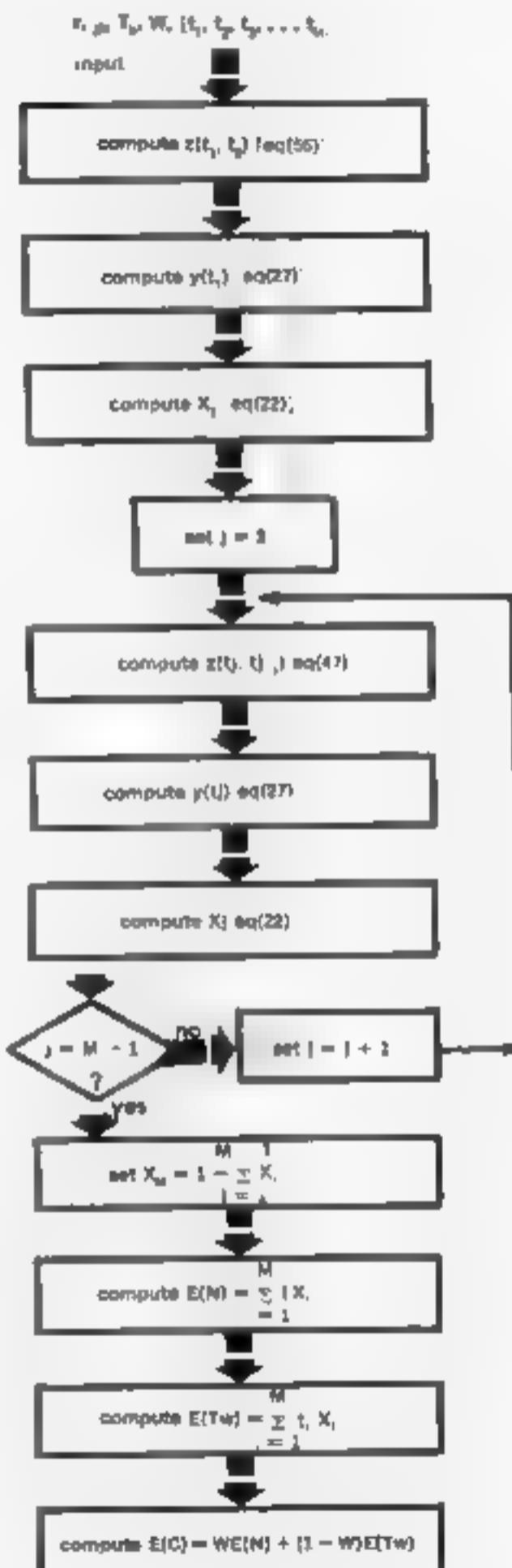


Figure 8—Program for Iterative Strategy.

## ANSWER

Proof that

$$z(t_{j-1}, t_{j-1}) = \frac{z(t_{j-1}, t_{j-2})}{z(t_{j-1}, t_{j-2})(1-r) + r} \quad (46)$$

We recall

$$\begin{aligned} z(t_{j-1}, t_{j-1}) &\leq \Pr[TB(t_{j-1}) | \tilde{SB}(t_{j-1})] \\ &= \frac{\Pr[TB(t_{j-1}) \cap \tilde{SB}(t_{j-1})]}{\Pr[\tilde{SB}(t_{j-1})]} \end{aligned}$$

But

$$\begin{aligned} \Pr[TB(t_{j-1}) \cap \tilde{SB}(t_{j-1})] &= \\ &= \Pr[TB(t_{j-1}) \cap SB(t_{j-1}) \cap \tilde{SB}(t_{j-1})] \end{aligned}$$

Since  $TB(t_{j-1}) \cap SB(t_{j-1}) = TB(t_{j-1})$  it follows that

$$\begin{aligned} z(t_{j-1}, t_{j-1}) &= \\ &= \frac{\Pr[TB(t_{j-1}) \cap \tilde{SB}(t_{j-1})]}{\Pr[\tilde{SB}(t_{j-1})]} \\ &= \frac{\Pr[TB(t_{j-1}) | \tilde{SB}(t_{j-1})] \cdot \Pr[\tilde{SB}(t_{j-1})]}{\Pr[SB(t_{j-1}) | \tilde{SB}(t_{j-1})] \cdot \Pr[\tilde{SB}(t_{j-1})]} \\ &= \frac{\Pr[TB(t_{j-1}) | \tilde{SB}(t_{j-1})]}{\Pr[SB(t_{j-1}) | \tilde{SB}(t_{j-1})]} \end{aligned}$$

The denominator can be written as:

$$\begin{aligned} \Pr[SB(t_{j-1}) | \tilde{SB}(t_{j-1})] &= \\ &= \Pr[TB(t_{j-1}) | \tilde{SB}(t_{j-1})](1-r) + r \end{aligned}$$

Thus

$$z(t_{j-1}, t_{j-1}) = \frac{\Pr[TB(t_{j-1}) | \tilde{SB}(t_{j-1})]}{\Pr[TB(t_{j-1}) | \tilde{SB}(t_{j-1})](1-r) + r}$$

Substituting (26):

We conclude

$$z(t_{j-1}, t_{j-1}) = \frac{z(t_{j-1}, t_{j-2})}{z(t_{j-1}, t_{j-2})(1-r) + r}$$

## APPLICABILITY

The applicability of the above algorithm, in terms of its usefulness in an ongoing system, is predicated primarily on the assumptions made in modelling the system. Recall that two major assumptions were made. The first, regarding the terminal user, is that the time a terminal is in use is exponentially distributed with a mean of  $T_0$ . Although there are several factors, such as multiple address and multiple messages per connection, which do not "fit" the exponential distribution, it is felt that these complications are not significant and that the assumption is reasonably valid.

The second major assumption is that of modelling the network by a fixed utilization factor ( $r$ ). This assumption "holds up" if the traffic (and dialouts) from the computer to the network represents only a small fraction of the overall network traffic.

## ACKNOWLEDGEMENT

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A. B. Wadler, Manager of Model Development and Simulation Design in the System Analysis Group, is responsible for the design and development of various mathematical and simulation tools for the evaluation of ISCS-I and the design of ISCS-II.

He joined Western Union in 1966. His previous experience has been at General Precision Aerospace working on inertial guidance system evaluation, and at Curtiss-Wright Electronics designing aircraft and missile system simulators.

Mr. Wadler is a graduate of City College of New York where he received a B.S. in 1955. He also has done graduate work in mathematics at Brooklyn Polytechnic Institute.



**[Our Customer Says:]**

## Punched Card Transmitter

### Speeds Handling of

## **CN** Railways Reservation System

by A. J. Kuhr

Director of Marketing

Canadian National Telecommunications

Instant return reservations are now provided by Canadian National Railways by means of its new computerized Electronic Passenger Reservation System, the first such system to be used in North America. The computerized system was designed by CN Railways' subsidiary, Canadian National Telecommunications, to handle the increasing volume of traffic and provide faster response to customer reservation requests. The unique new system links passenger agents throughout Canada to a central computer in Toronto via microwave and 100 wpm communication networks. Mr. Garth Campbell, General Manager of CN Railways in Montreal, says, "It would have been impossible to handle the Expo 67 reservations last year, if it had not been for the Electronic Passenger Reservation System."

### EPRS

The Electronic Passenger Reservation System EPRS, as developed by CN Telecommunications working with Western Union and Collins Radio, has four basic components, common to most computerized systems; namely, an input device, computer/communications interface, Central Processing Unit, and output device. The input device is a Western Union Punched Card Transmitter, #11890; the computer used is Collins Radio C-8401, and the output device is a Model 32 Teletypewriter. It was not economically practical to provide a direct line from each input device to the computer, because of the cost of lines and the number of terminals on the computer multiplex processor. By employing a network of Line Concentrators



# Telecommunications

100 agents sets have access to 10 computer terminals. When the system is queried, the output device produces a record of the request and the answer immediately beside it, on a single sheet, which may be used to answer the customer request.

#### Input

The Western Union Punched Card Transmitter was specially modified as input to the CN Railways Reservation System. It accepts cards prepunched or pencil marked in Hollerith code by the ticket agent with information regarding customer requests for space. The ability to read prepunched cards permits prepunching repetitive information by machine. The card, illustrated in Figure 1, is divided into eight command fields:

1. Type of request, Reserve, Cancel, Query or Test
2. Accommodation required; Parlor Car Seat or Coach Seat
3. Boarding Point
4. Destination Point
5. Quantity of Seats
6. Train Number
7. Car Number
8. Chronological date

As the customer telephones the Reservation Bureau, or appears at the ticket agent's counter, the agent marks a data card, using a soft lead pencil (some fixed information may be prepunched on the card before it is pencil marked). Marking time varies from 5 to 30 seconds. The Agent then places the card in the Punched Card Transmitter, as shown in Figure 2. When the START button on the data card transmitter is pressed, a direct line connection to the computer is established. The card is scanned and the information read by the transmitter, and then transmitted over telegraph channels at 100 wpm (baudot code) via a line concentrator, and then on to the computer. Information is simultaneously printed on the Model 32 teletype to permit verification of card marks.

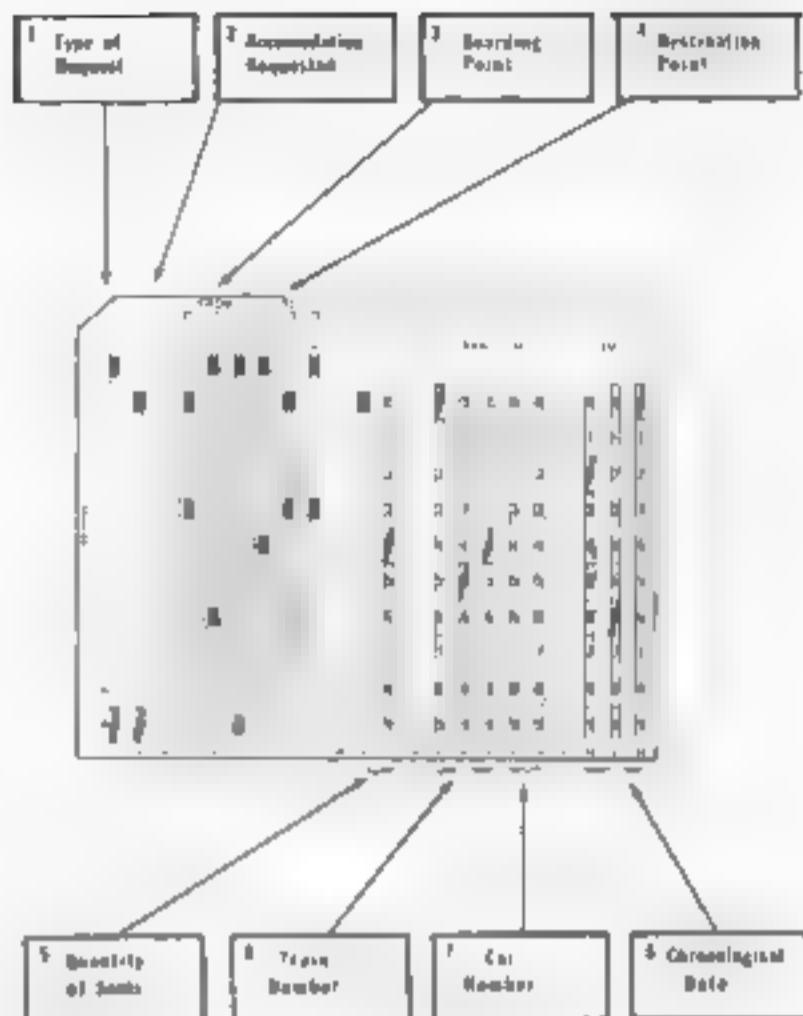


Figure 1—Typical Data Card Marked with a Request for Reservation



Figure 2—Agent's Desk Showing a Model 32 Teletype and a W.U. Punched Card Transmitter Located Below It.

## Computer Center—Data Central

The Computer Center known as Data Central, was formerly used by CN Railways for message switching only. The author of this article, Mr. A. J. Kuhr, Director of Marketing, and the designer of the Electronic Passenger Reservation System, Mr. F. J. Butterfield, are shown at the disc files in DATA Central in Figure 3. It consists of two Collins C-8401 processors, two core frames with 61K of 16 bit words, and two Bryant disc files. One processor performs message switching and reservations functions. The other is on "hot standby" and is ready to take over the complete operation in the event of a failure in the first processor. The disc files, with a capability of 153 million information bits, are normally both in operation. 13 million bits are used for the passenger reservation system. All of the required information for the operation is stored in duplicate, one copy on each file.

An inventory of available space is maintained in the Computer Center. When the Computer is queried regarding available space, it replies within a few seconds. The reply may be prefixed with "OK," "UN," "INV," or "CLOSED."

If "OK" is received, it means the reservation is made, and the computer has readjusted the inventory accordingly.

The prefix "UN" indicates requested space is unavailable in one car. The computer then scans the inventory of the train and sends out informa-

tion on the space that is available in each car of the train.

If an "INV" is received, it means the request as received is invalid, indicating the card has not been properly marked. The "INV" will be followed by three additional letters to indicate the columns in error.

"CLOSED" means the space requested has been closed out and is not available for sale.

## Transmission Speed

Both the message switching and the reservation systems use 100 wpm baudot code. This speed is most convenient, partly because it easily produces hard copy on the teleprinter. Terminal equipment is inexpensive and easy to maintain. The baudot code was chosen because of resultant basic economies in both the equipment and the computer programs.

## Transaction Time

The theoretical execution time, from the time the start button is pressed until the transaction is complete, is 12.3 seconds. Actual execution time is averaging 16 seconds. The few seconds difference is a result of heavy peak hour traffic, which extends the processing time from 3.3 seconds to a maximum of 6 seconds—and occasional delay in the concentrators finding idle lines into Data Central.

Figure 3—Mr. A. J. Kuhr, on the left, author of this article, discusses the merits of the Computer at Data Central with Mr. F. J. Butterfield, right, designer of the system.



## Output

The Model 32 teleprinter, as previously stated, prints the text of the message transmitted to the computer. Seconds after, the response to the request is printed beside it, on the same hard copy, as a reply to the ticket agent or operator.

Figure 4 illustrates a typical printout of the request. The transaction is explained in detail below it.

For example, if a request is made for 4 seats on a specific train for a particular day, between two points, the computer searches the inventory of the complete train to find 4 seats in one car. If they are not available, the computer reply is:

UN08/02/03/03

TORABZ TORML 04 054 260 OK04 05403 SEPT 17 257/1607

Figure 4—Typical Printout of a Request and a Reply

#### Explanation of Typical Printout

## REQUEST

Toronto station set "A" requests a reservation for coach seat space from  
TOR A R Z

Toronto to Montreal for four passengers on train number 054 in any car  
TORONTO 04 054

The reservation is required for September 17  
260

## REPLY

Reservation is confirmed for four seats on train number 054 Car No. 03 for  
OKO4 05403

September 17 The request is filed on September 14 at 12.07 Eastern Daylight  
**SEPT 17** **257/1607** Saving Time.

### New System vs The Old

The previous reservations system for club car space was based on a manual card record, maintained at the train's departure point as shown in Figure 5. Customers at a distant city often waited a considerable time before a reservation was confirmed, since the request for space had to be telegraphed to the city. Space was manually assigned. If available and a reply telegraphed to the requesting office. It was often more than a day before the customer was told that his reservation was confirmed.

Coach space was formerly sold without reservation. This inevitably resulted in occasions when trains were overcrowded with coach passengers. Such situations could be alleviated by attaching extra cars to the train at the last moment—but this in turn resulted in schedule delays, and in extra handling costs.

Since the system was installed the amount of train space stored in the computer's inventory has tripled. From an initial 10,000 trains per day

the system has expanded to the point where it is currently handling 25,000 to 26,000 trains per day. The system is actually an interim one, and is limited to coach and parlor car space. Within the next year, it is planned to include sleeping car reservations too—providing the advantages of a completely automatic system. As it is currently operating, the CN computerized reservation system provides several major advantages:

1. Fast handling of reservations for distant cities (10-16 seconds) compared to maximum of 2 days with the old system
2. Centralized control: Statistics and inventory in computer memory
3. Inexpensive input data cards—about \$1.50/1000
4. Simple operation—no special operator skills required
5. Capable of expansion
6. Uniform loading ensured—more efficient use of rolling stock

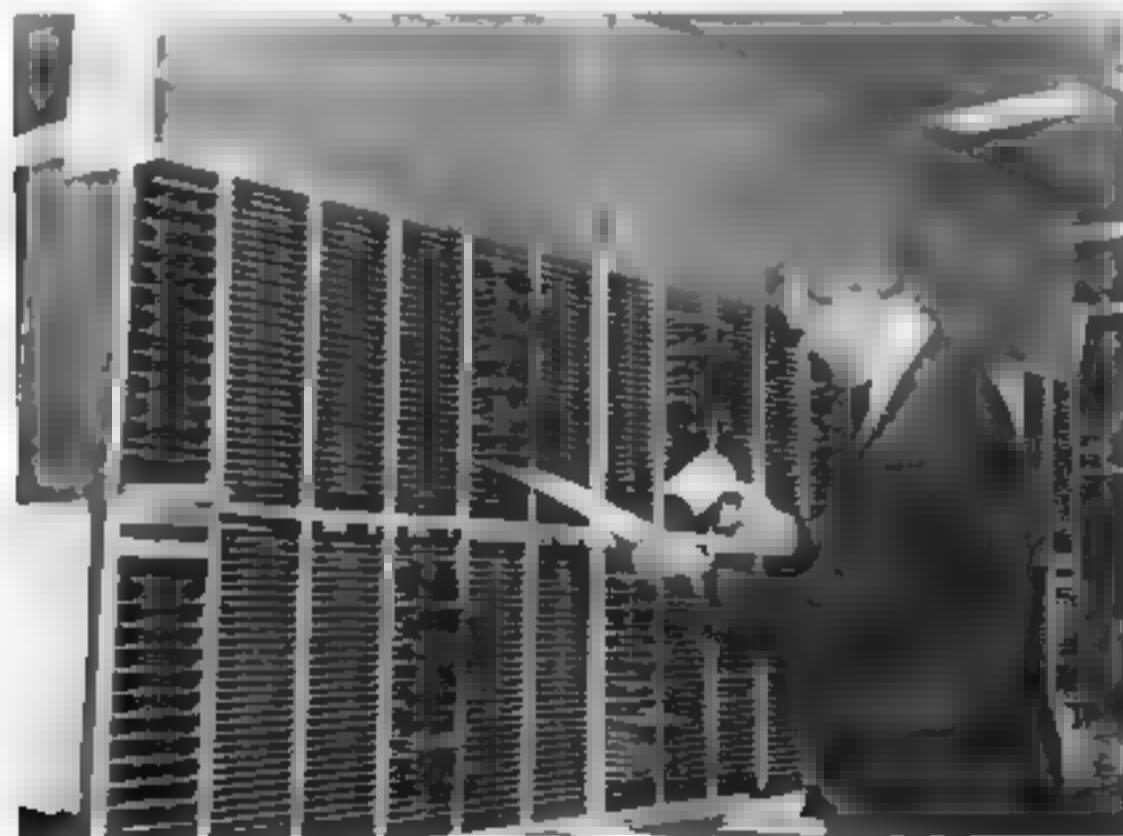


Figure 5—Train Departure Point Showing Old Method of Taking Reservation

## Western Union P.C.T.

One of the essential requirements of the reservation system was a capability for expansion and adaptation to future requirements. The Western Union Punched Card Transmitter is particularly suitable to system expansion, since it accepts various formats of information on its data cards. Some information may be prepunched, and new formats can be implemented readily by issuing new cards to the agent.

Other types of inputs were investigated during design of the Electronic Passenger Reservation System—such as rotary switch, display types and stylus types. The Western Union #11890 Transmitter was chosen because of its versatility and economy. Other systems accept the standard Hollerith card only, whereas the Western Union unit can accept shorter length cards—and half size cards reduce transmission time.

In order to provide prompt service to customers at the agent's desk at the counter, or by telephone at Telephone Reservations Bureau, each agent's set must have quick access to the computer. Also, the computer must have a quick return path to the agent's set for its response. To achieve this, when the "START" button on the Punched Card Transmitter is pressed, a direct line connection to the computer is established. This connection is held until the computer response is complete; it is then released.

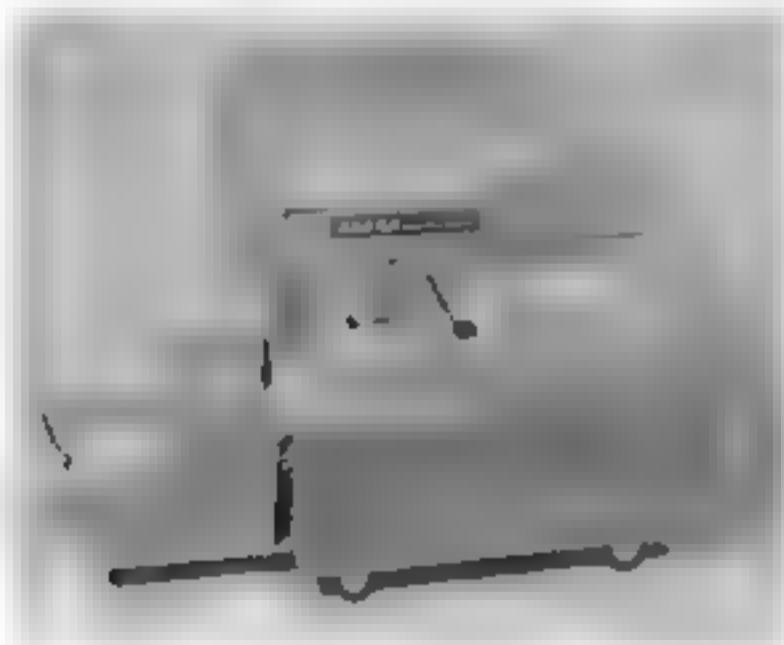


Figure 6—Western Union Punched Card Transmitter  
#11890

The major advantages of the Western Union Transmitter can be summarized as follows:

1. Ease of operation—no special skills required.
2. Versatility: Accepts punched or pencil marked cards, standard Hollerith or half size cards.
3. Reduced "talk time" to obtain reservation clearance.
4. Reduced holding time.
5. Simple equipment maintenance.
6. Improved overall service.
7. Universality—the unit can be used in several applications.

## Satisfaction with the System

Canadian National Railways finds that the expense of installing the Electronic Passenger Reservation System has been more than justified by improvements in service, by increases in the average loading of all trains under reservation (insuring uniform loading and efficient use of rolling stock), and by the effect which the system has had on the handling of peak traffic volume.

The combining of the reservations system in the same computer which is performing message switching functions has worked out well, the reservations system response time is satisfactory.

Certain very useful developments can be made. The possibility exists, for example, of having the reservations system generate reports on train sales and introduce them into the message system for delivery. The system has the capability of expansion to meet additional future requirements.

The present system handles all coach and club car reservations. The next stage, the extension of the system to handle sleeping car reservations, is scheduled for Spring 1969. A number of refinements and improvements leading to a more complete integration of reservations, ticketing and crowd control functions are possible. The benefits of this expansion will be apparent in reduced cost per reservation made, and in service improvements through all stages of issuance, handling and honoring of transportation reservations. ■

# EDITS— ELECTRONIC DATA INFORMATION TECHNICAL SERVICE

— New Management Tool for Effective Maintenance

by R. J. Robinson

The maintenance of Western Union services is as important as their design and development. EDITS, (Electronic Data Information Technical Service), a computerized information system, is a new management tool designed by Western Union for upgrading maintenance and improving Western Union services. The approach to this design was to measure the interruptions to service such as circuit troubles, preventative maintenance, installation and removal of components.

In the EDITS system, information regarding chronic interruptions to service, and information pertinent to removal or installation of equipment is received from customers at our Customer Service Centers, CSCs, (which also originate portions

of the system input). This system input covers four major record, or report categories:

1. General Field Activities—concerning maintenance and originating in Customer Service Centers
2. AUTODIN Plug in Failure Records—pertaining to the maintenance of components of the computer and peripheral equipment used in AUTODIN
3. AUTODIN Tributary Activities—covering the maintenance of all tributaries to AUTODIN
4. GSA/ARS Activities—concerning maintenance of switching equipment for the General Services Administration Advanced Record System, GSA/ARS and its tributaries.

### **Customer Service Centers**

The customer Service Center is an office established to coordinate the maintenance service within its given area. Approximately sixty of these Customer Service Centers are planned for strategic locations throughout the United States, of these thirty two are presently operating successfully. Customer Service Centers receive reports of trouble directly from the customer, initiate corrective action with the associated Wire and Repeater Test Room or maintenance dispatcher, and

C/C/C		DATE		CIRCUIT ON SERVICE		DROP AFFECTED		REP-ABLY		TRUBLE LOCAT ON		D	
1	2	3	4	5	6	7	8	9	10	11	12	13	14
11	12	13	14	15	16	17	18	19	20	21	22	23	24
25	26	27	28	29	30	31	32	33	34	35	36	37	38
39	40	41	42	43	44	45	46	47	48	49	50	51	52
53	54	55	56	57	58	59	60	61	62	63	64	65	66
67	68	69	70	71	72	73	74	75	76	77	78	79	80
81	82	83	84	85	86	87	88	89	90	91	92	93	94
95	96	97	98	99	100	101	102	103	104	105	106	107	108
109	110	111	112	113	114	115	116	117	118	119	120	121	122
123	124	125	126	127	128	129	130	131	132	133	134	135	136
137	138	139	140	141	142	143	144	145	146	147	148	149	150
151	152	153	154	155	156	157	158	159	160	161	162	163	164
165	166	167	168	169	170	171	172	173	174	175	176	177	178
179	180	181	182	183	184	185	186	187	188	189	190	191	192
193	194	195	196	197	198	199	200	201	202	203	204	205	206
207	208	209	210	211	212	213	214	215	216	217	218	219	220
221	222	223	224	225	226	227	228	229	230	231	232	233	234
235	236	237	238	239	240	241	242	243	244	245	246	247	248
249	250	251	252	253	254	255	256	257	258	259	260	261	262
263	264	265	266	267	268	269	270	271	272	273	274	275	276
277	278	279	280	281	282	283	284	285	286	287	288	289	290
291	292	293	294	295	296	297	298	299	300	301	302	303	304
305	306	307	308	309	310	311	312	313	314	315	316	317	318
319	320	321	322	323	324	325	326	327	328	329	330	331	332
333	334	335	336	337	338	339	340	341	342	343	344	345	346
347	348	349	350	351	352	353	354	355	356	357	358	359	360
361	362	363	364	365	366	367	368	369	370	371	372	373	374
375	376	377	378	379	380	381	382	383	384	385	386	387	388
389	390	391	392	393	394	395	396	397	398	399	400	401	402
403	404	405	406	407	408	409	410	411	412	413	414	415	416
417	418	419	420	421	422	423	424	425	426	427	428	429	430
431	432	433	434	435	436	437	438	439	440	441	442	443	444
445	446	447	448	449	450	451	452	453	454	455	456	457	458
459	460	461	462	463	464	465	466	467	468	469	470	471	472
473	474	475	476	477	478	479	480	481	482	483	484	485	486
487	488	489	490	491	492	493	494	495	496	497	498	499	500

Fig. 1.—Input—Central Field Activity Record

monitor each activity until the interruption is restored

The necessary data is filled in on the input activity record and subsequently transmitted to the computer in New York where a computer record of each customer's service is maintained.

Each message may contain up to 150 activities. At the end of the reporting period the computer processes the information according to one of the software programs and then prints out a weekly report, for all levels of management in

Spring 1968

Fig. 2—Output—Weekly Printout, Report to Management

the Technical Facilities Department.

The General Field Activities report or the Input Activity Record contains 24 fields of data, as follows:

Field 1	—identifies the program or type of report
Field 2	—identifies the reporting CSC
Field 3	—identifies the starting date of the activity
Field 4 & 5	—identifies the circuit, service number and drop affected (or in trouble)
Field 6	—identifies the division of supervisory responsibility for the activity
Field 7	—identifies the type of activity or card code. There are 9 types of activity shown in Table I
Field 8	—identifies the office call(s) from the troubled location, i.e., if the problem was a facility failure between New York and Chicago, the identification, "NQCC" is entered in this field.
Field 9	—for entry of additional information, when required, pertaining to the same activity in another record
Field 10	—indicates the nature of the trouble as reported by the customer. (See Table II)
Field 11	—identifies the particular unit of equipment or service in trouble i.e., A Telex 28 ASR Set would be coded "122"
Field 12	—identifies that part of the equipment failure, i.e., a Code "22" indicates the Automatic Answer Back is inoperative
Field 13	—further defines the failure. A code of "H" would indicate a mechanical adjustment was necessary to correct the problem.

It is evident that Fields 11, 12 and 13 provide precise trouble definition.

Fields 14-21	—trace the time consumed in correcting the trouble activity. These time fields provide the basis for calculations which determine total time of outage, and manpower utilization. For example, the difference between Field 14 and 15 yields the W & R Delay time. Similarly, the difference between Fields 17 and 18 indicates the Maintainer Travel time. Prior to the implementation of the EDITS System, such data was not available to management for measuring manpower usage
Field 22	—is used for the initials of the Maintainer or Technician who was involved in the activity
Fields 23 & 24	—is normally used only in conjunction with an installation activity. Field 23 indicates the PM interval and Field 24 indicates the PM route. This information is stored in the data base for use in scheduling Preventive Maintenance

TABLE I

Card Code Identification	
Type No.	Code Identification
1	Service Interruption (Trouble)
2	Preventative Maintenance
3	Change Order or Engineering Revision
4	Overtime Usage
5	Equipment or Service Installation
6	Equipment or Service Discontinuance
7	Equipment or Service Relocation
8	Other types of activities
9	Service Interruption (No lost time)

TABLE II

Reported Trouble	
Type No.	Nature of Trouble
A	Receiving Problem, Circuit
B	Receiving Problem, Equipment
C	Receiving Problem, Unknown
D	Sending Problem, Circuit
E	Sending Problem, Equipment
F	Sending Problem, Unknown
G	Unknown

#### Data Collection

The Customer Service Centers transmit daily activity records from a premarked card in message format via the Western Union Telex Network, to the Telex Communications Service (TCCS) System New York. The first line of the message format contains a unique routing indicator which, when recognized by the TCCS System, actuates message routing to a magnetic tape containing a record of all input to the TCCS System. Upon recognition of the end-of-message sequence, line N + 1, the TCCS transmits "EDITS ACCEPTED" back to the sender, advising him his message has been accepted and stored on tape.

Each Monday evening the accumulated EDITS messages are stripped off the TCCS tapes and an EDITS Journal Tape is created containing only the EDITS messages collected during the past week. The messages are stored sequentially on the tape as they were received. This tape becomes the input to the EDITS Collection Sort program.

## Hardware

The EDITS System basically comprises the Univac 418 computer and the following peripheral equipment configuration, as shown in Figure 3

1 High Speed Printer/Card Reader

1 Magnetic Drum Storage Unit

6 Magnetic Tape Drives

The Univac 418 which processes all EDITS reports, is a medium scale digital computer with 65K words of magnetic core storage.

The Magnetic Drum Storage Unit provides mass storage capacity of 262K words, and is used to store activity records and reference tables.

The Magnetic Tape Drives provide the input medium for data base tables (updated at completion of each general field report) as well as all accepted activity information.

The High Speed Printer provides all report printouts.

## Software

Three basic software programs are used in the implementation of EDITS: These are EDITS Collection Sort, Report Processing and History Search Programs.

1) The EDITS Collection Sort Program, illustrated in Figure 4, is employed to validate the message format and to rework the raw material into a format acceptable to the Report Processing Program.

Message header validation consists of checking the header format and the "P" digit Program identifier for correctness. Invalid information causes message rejection and appropriate printout of the High Speed Printer.

Activity record validation consists of checking each activity record's "PCS" Program Identification—Customer Identification Number, against the message header's "PCS." The length of the activity is also checked against the prescribed number of characters for the specific activity.

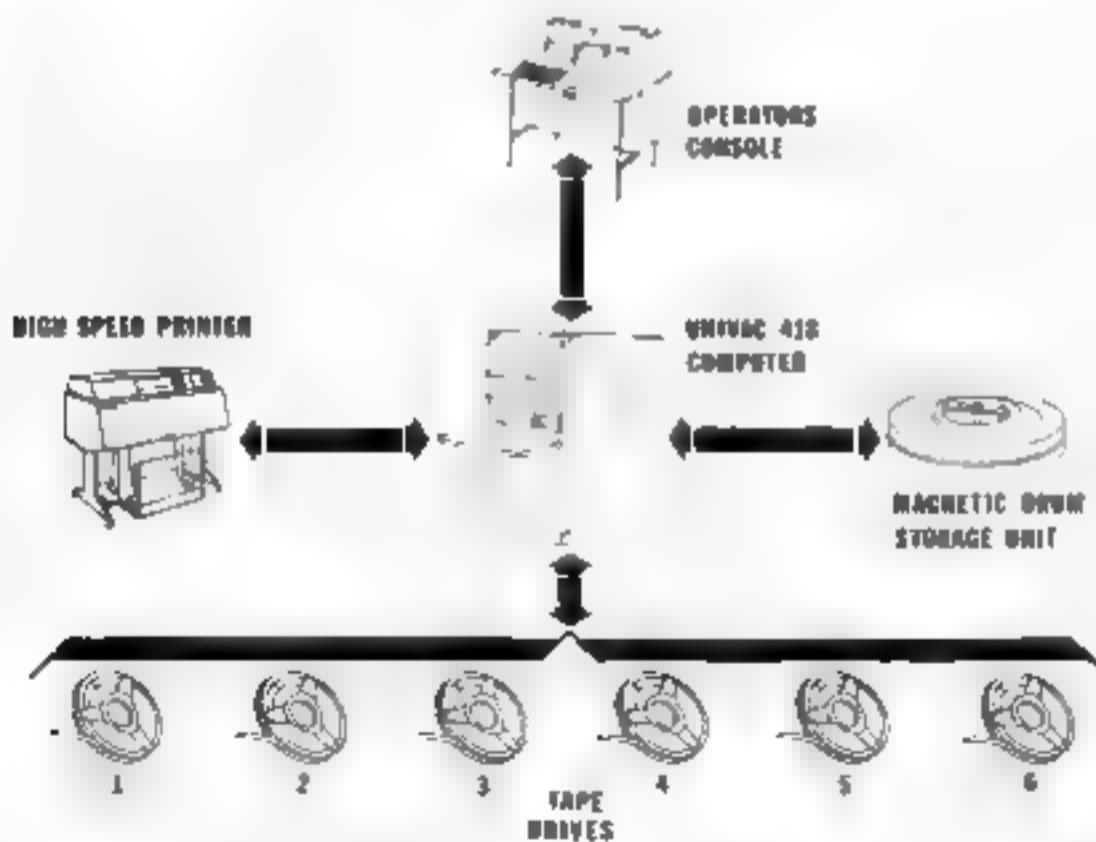


Fig. 3—Components of EDITS System

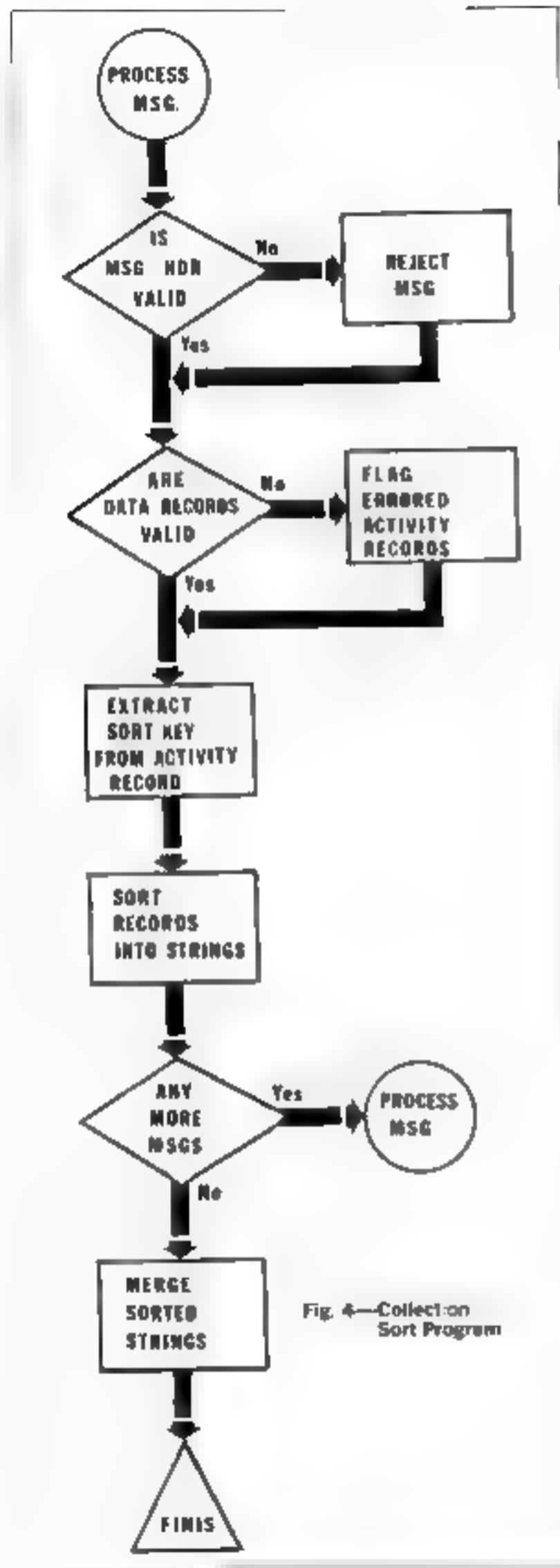


Fig. 4—Collection Sort Program

Any test that fails causes that activity record to be flagged for rejection by the Report Processing Program.

2) The Report Processing Program requires that activity records be ordered according to the following key

#### PROGRAM CSC, CIRCUIT NUMBER DATE, TIME OLT

This key is extracted from each activity record and the records sorted into strings of not more than 600 activity records each. Finally the sorted strings of records are merged to produce a final output tape in proper order for report processing.

The Report Processing Program, illustrated in Figure 5, consists of a control segment plus additional segments for each type of report to be produced. Operator action is required to load the common segment into the computer, establish priority for report processing, and initiate the program. No further operator intervention is required. The common segment controls the processing of each report. Reports are processed in sequential order as specified.

3) History Search Program—In addition to the weekly EDITS reports, historical information may be obtained by a request for a computer search through activity records for specified fields. Searchable fields, may be specified in any combination.

It is anticipated that the Electronic Data Information Technical Services system will be capable of providing a source of statistics on virtually any component in any Western Union system.

#### SYSTEM OUTPUT

Output of the General Field Report is a printout presented in six sections, each of which is described as follows.

The accuracy of the output reports depends upon receiving correct data from each CSC. Therefore, each activity record is extensively tested for validity. Section One tabulates all records that do not pass these tests. An exact copy of the input record is printed with the field in error shown to the left. The "F12" errors indicate the Sub-assembly code of "01" is not valid for the Unit Codes given. In this case, the Sub-assembly code was changed to "00—UNDETERMINED" and processing continued. If a non-correctable

error was encountered, such as a non-existent circuit number, the notation "F4 ERROR REJECT" would appear to the left of the record and the record rejected.

Section Two lists all of This Week's troubles (Card Code 1) that have exceeded a predetermined outage threshold.

Section Three lists all activities involved in two or more troubles (Card Codes 1 or 9) in two weeks. When the criteria is met, all activities for the particular circuit are listed as reference information. The "E" between the DATE and CKT DENT columns for X 615 indicates there was an error in the input activity record. Reference to Section One will define the error.

Section Four of the weekly report, shown in Figure 6, lists all activities that affect the state of the data base. Installations, removals, and changes are shown, along with the associated PM route and interval.

Section Five, shown in Figure 7, is a summary of performance and manpower utilization. It is presented in three parts indicating major time units of manpower usage, circuit problems, and equipment problems.

Part A compares a This Week's vs Last Week's use of manpower for the purpose of pointing up specific areas where service improvement may be required. Each category of activity (Card Code) is shown with the number of activities and total time (in hours) involved. Total response times are shown for various types of service, i.e., Government, Stocks, Public Message System, and Private Wire Services.

Part B gives a breakdown of This Week's vs Last Week's circuit troubles (Card Codes 1 or 9) by type of trouble, i.e., Unknown Troubles, Western Union Facility Troubles, Customer Responsibility, etc.

Part C gives a breakdown of This Week's vs Last Week's equipment troubles (Card Codes 1 or 9) by equipment category to establish percentage of efficiency. The various categories of equipment are listed, with the total number of troubles and the time involved.

Careful scrutiny of Section Five will lead to the development of standards for maintenance services. Deviation from these standards will be readily noted, and corrective action in the proper areas will result.

Section Six, shown in Figure 8, lists the Preventive Maintenance schedule to be taken.



Fig. 5—Report Processing Program

SONOMA CHANGES AND INSTALLATIONS					
ACT	DAY	CAT ID/NAME	DROP	UNIT CODE	INITIAL
MMY	047	00000045	00000000	11A TPL TYPE 15	00 MWS
MMY	066	14000006	00000000	000 CIRCUIT ONLY	00 MWS
MMY	066	FL010001	00000000	032 FAX/065007100	00 MWS
MMY	066	741000341	00000000	121 TPL	00 MWS
MMY	066				00 MWS

END CSC 01 BUE WEEK SCHEDULE

GENERAL EDITS

SECTION FIVE

RESPON SOY RESPON

ENTRY TIME 0-3

Fig. 6, 7, 8—Weekly EDITS REPORTS

## Advantages of System

Among the many benefits to the Customer derived from EDITS, the following are most significant

1. Immediate detection of deterioration of service, before the customer recognizes it as a problem
2. Excessive failures and long outages are quickly recognized by Western Union supervisors and corrective action is quickly taken to ward off a reoccurrence
3. Automatic analysis of service difficulties is made possible for the first time and a more rapid response to these difficulties with corrective measures is achieved
4. More personalized attention to the handling of performance difficulties reported by the customer has been established in the CSCs. The appropriate technical resources of

Western Union are notified for prompt corrective measures. The difficulty is monitored by the Custom Service Coordinator until the difficulty is corrected and the activity is closed out

## Breakthrough in Customer Relations

EDITS has proven to be a real breakthrough in customer relations. The new computerized system accelerates maintenance of customer equipment and improves WU's overall services. EDITS provides a vastly improved service tool for constant supervision and fast action and the resulting protection of existing revenue. It is a move toward our basic objective of Real Time Service Supervision

\* \* \*

## References.

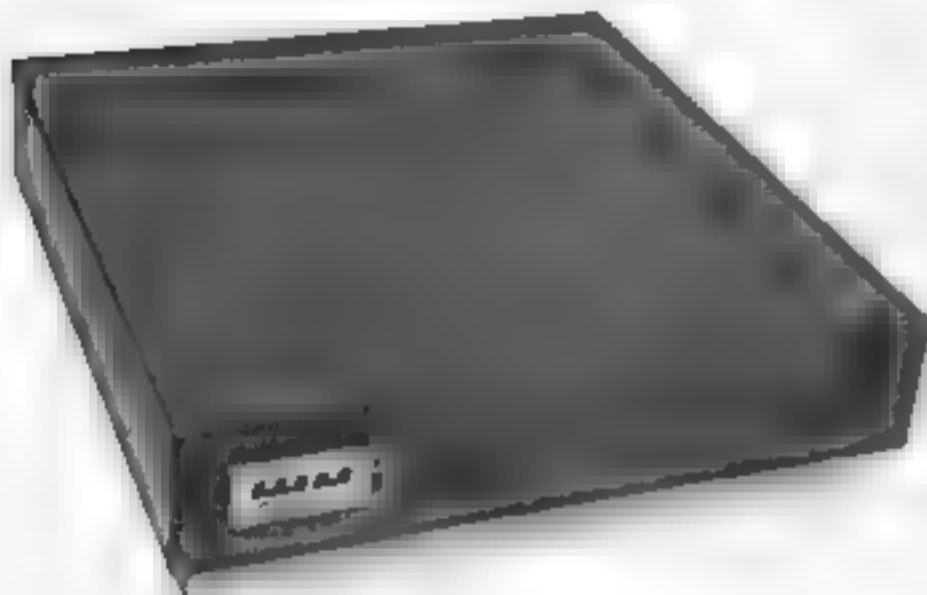
- 1—Telex Communications Computer Service, W U. TECHNICAL REVIEW—Winter 1968.



**R. J. ROBINSON**, Assistant General Supervisor of Technical Services in the Technical Facilities Department, is responsible for coordination of projects in the maintenance Analyst Group. He has been concerned with the design development and coordination of software for all data reduction programs. He was particularly involved in the programming of an information retrieval system for AUTODIN.

Mr. Robinson has been responsible for the programming of the EDITS system since its inception in 1966.

# New Western Union Modems



Two new modems have been introduced by Western Union which employ new advancements in transmission technology

Data Set 2247 permits 2400 bps transmission on over dedicated voice grade circuits and on Broadband Exchange Service (BEX)

Data Set 2481 allows 4800 bps transmission on conditioned dedicated or circuit switched networks such as BEX

## Data Set 2247

- Synchronous Transmission at 2400 Baud
- Differential Eight Phase Modulation
- Double Sideband Transmission
- No Code Restrictions
- Full Duplex or Half Duplex Operation
- Full Duplex 75 Baud FSK Secondary Channel (Optional)
- Interface Connector meets EIA Standard RS-232 B (Oct 65)
- EIA RS 232 Contact Closure Interface (Optional)
- Alternate Voice/Data or Data-Only Operation
- Compatible with W.U. Automatic Answering Unit 11774-A
- Compatible with W.U. Automatic Calling Unit 12405-A
- Fixed (Compromise) Equalizer which may be required.

## Data Set 2481

- Synchronous Transmission at 4800 Baud
- Eight Phase Modulation
- Double Sideband Transmission
- No Code Restrictions
- Full Duplex or Half Duplex Operation
- Interface Connector meets EIA Standard RS 232-B (Oct 65) or MIL Std 188-B
- Alternate Voice/Data or Data-Only Operation
- Compatible with W.U. Automatic Answering Unit 11774-A
- Compatible with W.U. Automatic Calling Unit 12405-A
- Adjustable Equalizer and Delay Indicator for Operation over W.U. Class G (Telco 3002) Voice-Grade Channels with Type C2 Conditioning
- All Solid State Circuitry

# Patents Recently Issued to Western Union

Inventor	Patent No.	Title
G. H. Ridings and D. M. Zabriskie	3,296,622	Sheet Holding and Releasing As- sembly For Facsimile Scanner Drum
J. J. Krakusky	3,301,954	Blank Deleter
John Elich and F. J. Masciandaro	3,304,367	Regenerative Repeater
Harry C. Liket	3,304,500	FSK System Including Means For Distributing Data Pulses Into Two Channels To Modulate Two Sep- arate Carrier Frequencies
John H. Hackenberg and Garvica H. Ridings	3,313,884	Receiver Synchronized And Con- trolled Facsimile System
John Elich and John Joseph McManus	3,319,150	Solid State Regulated Power Sup- ply
Francis R. Firth	3,330,905	Telegraph Polar Adapter
Oscar W. Swenson	3,333,569	Metering Ribbon Inker
John L. McMahon	3,341,192	Automatic Sheet Transport Means for Message Scanning Apparatus
Ethan Aronoff	3,355,663	Waveguide Echo Measurement System

Computers  
Communication

McMains, T. F.: FCC Begins to Examine the Computer/Communications  
Western Union TECHNICAL REVIEW, Vol. 22, No. 2 (Spring 1968)  
pp. 38-42

The Federal Communications Inquiry was designed to explore regulatory and policy problems brought about because of the interdependence of computer and communications services and facilities. Some 55 communications companies and computer manufacturers responded to the FCC request.

This article summarizes Western Union's position on the subject. In it individual items are cited and the differences between the communication function and the data processing function are described. Western Union points out that the Communications Act of 1934 is adequate.

Test Measurements  
Impulse Noise

Seedman, A. J.: Measurement & Analysis of Impulse Noise for Communications Circuits  
Western Union TECHNICAL REVIEW, Vol. 22, No. 2 (Spring 1968)  
pp. 43-49

Studies made of impulse noise in communications systems indicate that the amplitude distribution curve follows a hyperbolic law.

This article points out the fact that a 3-point measurement of impulse noise satisfactorily defines the amplitude distribution. Tests of impulse noise are evaluated.

Computers  
Mathematical Analysis  
Circuit Switching

Wedler, A. B.: Computer-to-Terminal Ringback Algorithm  
Western Union TECHNICAL REVIEW, Vol. 22, No. 2 (Spring 1968)  
pp. 50-61

In designing an optimum algorithm which a computer can use in delivering messages through a circuit switching network, the basic problem is to determine the number of times the computer should dial to complete a connection.

The article analyzes the criteria, or cost factors involved, and develops mathematically the optimum condition. A case history for ISCS Phase 0 is described.

Products  
Announcements  
Communication Systems

Punched Card Transmitter Speeds Handling of  
Railway Reservation Systems  
Western Union TECHNICAL REVIEW, Vol. 22, No. 2 (Spring 1968)  
pp. 62-67

This article written by the Canadian National Transmitter, designed by Western Union and modified for application in the Electronic Passenger Reservation System developed by CNR Telecommunications for CN Railways in Toronto, Canada.

THESE ABSTRACT CARDS MAY BE CUT OUT AND PASTED ON LIBRARY CARDS FOR FILEING.

New Products  
Modems  
Transmission  
Announcements

New Western Union Modems  
Western Union TECHNICAL REVIEW, Vol. 22, No. 2 (Spring 1968)

P. 76

Two new modems introduced by Western Union permit more effective transmission speeds.

Data Set #2247 is designed for 2400 bps and Data Set #2481 is designed for 4800 bps.

This announcement tabulates the special features of each set.

Maintenance  
Service Improvement

Robinson, R. J.: EDITS—Electronic Data Information Technical Service  
Western Union TECHNICAL REVIEW, Vol. 22, No. 2 (Spring 1968)

pp. 68-75

EDITS—Electronic Data Information Technical Service was designed by Western Union as a management tool for upgrading service. Customer Service Centers transmit trouble activities, received from customers by phone, to a computer. Weekly reports of a printout of the troubles are available to management for scheduling Preventive Maintenance.

This article describes the basic software programs and the advantages of the system.

Telex  
Anniversaries  
Announcement

10th Anniversary of Western Union's Telex  
Western Union TECHNICAL REVIEW, Vol. 22, No. 2 (Spring 1968)

P. 80

Western Union Telex Service has increased in volume and revenue since 1957. Over 25,000 subscribers now use Telex in the United States and can be connected via international carrier to other Telex subscribers all over the world.

New Binders, for this new large size magazine, will be available with the Summer 1968 issue.

THESE ABSTRACT CARDS MAY BE CUT OUT AND PASTED ON LIBRARY CARDS FOR FILING.

# WESTERN UNION TELEX MARKS ITS 10th ANNIVERSARY

*Western Union Telex marks its 10th anniversary, on May 21 with revenues that have increased from \$33,000 in 1958 to more than \$37 million a year now, in 1968 and a record total of 25,000 Telex subscribers.*

*In 1958, Telex connected users in New York City only to those in Canada. Today, a subscriber to this steadily expanding service can exchange written communications and data with all other Telex users in the U.S., Canada, Mexico and, through facilities of the international carriers, with more than 35,000 Telex users throughout the world.*

*In addition to the continuing rapid expansion of the number of Telex subscribers, the growth of Telex revenues has been expanded by the new Telex Computer Communications Services, known as TCCS. A subscriber simply dials a Western Union computer to obtain these automatic services, which contribute to the convenience and versatility of the system. For example, through TCCS subscribers can send messages to customers of the Bell System's Teletypewriter Exchange Service—TWX.*

*Another TCCS is a multiple-address service, whereby the user can have the same identical message sent to a number of addressees automatically by computer. This frees the sender from having to transmit each message separately.*

*All Telex subscribers can now send messages through their Telex machines to non-subscribers in this country and around the world through the connecting overseas carriers. In effect, a Telex machine puts the world at the subscriber's finger tips.*